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TABLE OF CONTENTS.

ENGINEERING NEWS OF THE WEEK..... 117
The Nordberg Pumping Engine at Wildwood, Pa. (with two-page plate and other illustrations..... 118
The Systematic Location of Pipes and Wires in the Streets as Opposed to Subways..... 120
The Improvement of the South Pass of the Mississippi River (illustrated)..... 121
Contract Trial of an Allis Triple-Expansion Pumping Engine at the Chestnut Hill High Service Station of the Metropolitan Water-Works, Boston, Mass..... 125
A Defence of Australian Hardwood Pavements..... 126
Experience With Mechanical Scrapers for Cleaning Water Mains at Halifax, N. S..... 127
Diagram for Determining the Volume of Semi-Elliptical Groined Arch Vaulting (illustrated)..... 130
The Possibilities of Electric Heat as Limited by the Cost of Production..... 131
Comparative Estimates of the Cost of Combination and All-Steel Highway Bridges..... 132
Paris Exposition Awards to Engineering Exhibitors. 132
Machine Snow Plows on the Colorado Midland Ry.. 133
Prof. Pupin's Proposed System for Long Distance Telephoning..... 133
Plate Girder Park Foot Bridge at Madison, N. J. (illustrated)..... 135
Report of the Merchants' Association on the Water Supply of Greater New York..... 135
Railway Crossing Gates with Pipe Connections (illustrated) 140
EDITORIAL NOTES..... 128
The Record of Experience with the South Pass Jetties—How Much Water Can Be Wasted Through a ¾-in. Tap?—Commissioner Dalton on Water Filtration—A High Duty Pumping Engine Record, and the Method by Which it is Obtained—The Test of the Boston Allis Engine.
EDITORIAL:
The Water Waste and Future Water Supply of Greater New York (illustrated)..... 129
LETTERS TO THE EDITOR..... 130
A New Method of Attaching Brakes to Car Trucks —Notes and Queries.

THE EAST RIVER BRIDGE COMMISSION has been temporarily enjoined, by Justice Fitzgerald, of the Supreme Court of New York, from awarding the contract for building the two approaches to the bridge. The injunction is returnable Aug. 23, an order being given to show cause why the commission should not reject all the bids and readvertise under different specifications. It is alleged by the complainant, Mr. Julius Meyers, that the specifications, which call for acid steel, are unjustly framed, and that such steel is made only by the Carbon Steel Co., of Pittsburg, thus practically giving that company the power to dictate who shall be the successful bidder. The complaint further states that the specifications require the successful bidder to conform to Section 415 of the Laws of 1897, known as the labor law, which law, it is claimed, is unconstitutional. He also objects to the requirement that no firm which has not been in successful business for one year shall be allowed to compete, as unfair and unjust.

THE SYDNEY, AUSTRALIA, BRIDGE COMPETITION is discussed by Mr. J. A. L. Waddell, M. Am. Soc. C. E., in a letter published in the "Building, Engineering & Mining Journal," of Melbourne. We print the letter, as follows:

I have read over the conditions for the competition on the Sydney bridge, and have come to the conclusion that it is a case of "heads I win and tails you lose." Let us analyze the thing. The city offers prizes to the amount of about $7,500 for the two best plans. Let us assume that there are 20 plans prepared. Each plan, if properly gotten up, will cost in cash, say $1,500, making a total of $30,000. This is the value of the work done by the competitors for the city, and they pay $7,500 for it. Again, each bidder in addition to the preparation of the plans, has to put in a bid on the work, and will be called upon to back that bid with a $50,000 deposit; but even if his design is the most satisfactory, he has no assurance that the contract will be given to him, because the city buys the plans outright and can call for bids in competition on these plans. The city should have given the engineering with the usual 5% fee to the successful bidder in addition to the $1,000 prize. Had it done this it would have been worth while to compete, but as it stands, it is not. We have decided that under the circumstances it will not pay us to touch the work. I feel certain that they will get no designs from really reliable parties and competent bridge engineers in the United States.

J. A. L. Waddell.

Kansas City, Mo., March 29, 1900.

THE DADY SEWERAGE FRANCHISE granted by the city of Havana, Cuba, during the Spanish regime is again before the courts, and an injunction is asked to restrain Governor-General Wood from putting into effect the new charter of Havana, which would permanently annual Mr. Dody's contract.

A NEW WATER SUPPLY for St. Louis is proposed by Mr. P. H. Flynn, of Brooklyn, N. Y. He would abandon the Mississippi entirely and take a supply from the Meramac River at a point 80 miles distant from St. Louis, the water to be brought to the city in two 72-in. steel pipes. The total cost is estimated at $25,000,000.

A NEW WATER SUPPLY FOR NEW ORLEANS has been proposed by the firm of Morill & Cragin, which has made a proposition to supply at least 50,000,000 gallons a day of pure and wholesome water by gravity from a source free from contamination and not requiring filtration. The price asked is $42.50 per million gallons for not less than 50,000,000 gallons daily, or a higher price for a smaller supply, and the city would be required to purchase eventually the conduits to be laid at a cost of $12,000,000 to $15,000,000 for bringing the supply to the city. The New Orleans Board of Sewer and Water Commissioners were advised on Aug. 16 that the source of the new supply would not be definitely indicated, as options on the water rights were not secured, nor was the method explained by which the water from streams that are often muddy and turbid is to be rendered "pure and wholesome" without filtration. Meanwhile progress is being made with the investigations recommended by the Advisory Board of Engineers looking to the purification of the Mississippi River supply. Plans and specifications for sedimentation tanks have been completed, and current observations are in progress. Messrs. Rudolph Hering and Geo. W. Fuller have been engaged as consulting engineers.

THE WATER CONSUMPTION OF LONDON in the month of June, 1900, averaged 36.31 gallons per capita per day, the total daily consumption being 221,149,000 gallons, and the population estimated at 6,090,190. Of this supply, 124,122,000 gallons were from the River Thames, 52,346,630 gallons from the Lea and 44,678,000 gallons from springs and wells.

CENSUS RETURNS OF THE POPULATION of the principal cities are slowly being announced by the Census Bureau. The following figures have been given out up to date:

	1890.	1900.	Increase.	Per Cent.
Minneapolis	164,738	202,718	37,980	23.05
St. Paul	133,156	163,632	30,476	22.89
Milwaukee	204,468	285,315	80,847	39.54
Cincinnati	296,908	325,902	28,994	9.77
Buffalo	255,664	352,219	96,555	37.77
Washington, including Georgetown	202,978	232,745	29,767	14.67
Louisville	161,129	204,731	43,602	27.06
Providence	132,146	175,597	43,451	32.88
Chicago	1,099,850	1,698,575	598,725	54.44
New York—				
Manhattan	1,441,214	1,850,093	535,299	35.33
Bronx Borough	74,087	200,567		
Brooklyn "	838,547	1,166,582	407,727	41.66
Queens "	88,635	152,999		
Richmond "	51,693	67,021		
Total New York	2,494,176	3,437,202	943,026	37.81

In 1890 the city of New York comprised all of what is now the Borough of Manhattan and all of what is now the Borough of The Bronx, except the territory lying to the west of the East River annexed on January 1, 1898. The population of New York in 1880 was 1,206,299, and in 1890, 1,515,301, showing an increase from 1880 to 1890 of 308,002, or 25.62%. The slowness of growth of Cincinnati is explained by the overflow of the population into the electric-car zones beyond the city limits, especially over the Ohio River into Kentucky. The population of Chicago in 1880 was 503,185, showing an increase of 596,665, or 118.58%, from 1880 to 1890. The population of Minneapolis in 1880 was 46,887, showing an increase of 117,851, or 251.35%, from 1880 to 1890. The population of St. Paul in 1880 was 41,473, showing an increase of 91,683, or 221.07%, from 1880 to 1890.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred at Pierson, Mich., on the line of the Grand Rapids & Indiana R. R., Aug. 15. Two passenger trains met in a head-on collision, resulting in the death of nine persons, the serious injury of eight others, and the destruction of the engines and baggage cars. The accident was due either to a misunderstanding on the part of the engine-men or inability to see the signals. There was a dense fog at the time.——A rear-end collision, resulting in three deaths, occurred at Kensico, N. Y., on the Harlem Division of the New York Central R. R., Aug. 21. An extra freight train loaded with ice ran into the regular freight standing at the station.

THE TEHUANTEPEC R. R. in Mexico, extending between the Atlantic port of Coatzacoalcos and the Pacific port of Salina Cruz, is to be extensively improved, in accordance with a contract recently entered into between the Mexican government and the contracting firm of S. Pearson & Son, of London, Eng. The firm named is to take over and operate the roads and is to complete certain specified improvements within 3½ years. The firm is to receive a government subsidy of $5,000,000 and losses or profits from the operation of the road are to be divided equally between the firm and the government.

AN ELECTRIC RAILWAY, equipped with the third-rail system is being built between Albany and Hudson, N. Y., by the Albany & Hudson Ry. & Power Co. This company purchased the Kinderhook & Hudson Ry., which has heretofore been operated by steam power. The new owners have remodeled the system and have extended the line from Niverville, the previous terminus, to Rensselaer, an additional distance of 18 miles. The total length of the new road from Hudson to Albany is nearly 38 miles. The power for operating the road is supplied from one power station, located at Stuyvesant Falls, and driven by water-power, from which current will be transmitted at 12,000 volts to substations along the line. The construction of the road has cost $2,500,600. Ten miles of the road are now in operation, and it is expected that the entire system will be completed within a month. The Chief Electrical Engineer of the road is Mr. Ernest Gonzenbach.

TELEPHONIC COMMUNICATION from the staterooms of ocean-going steamships when at their docks at New York, is to be furnished by the New York & New Jersey Telephone Co. A central switchboard will be provided on board the vessel, from which a multiple conductor cable will pass to the deck. The end of this will be provided with a coupling to fit a similar one attached to a cable on shore. The latter will lead to one of the city exchanges. By this arrangement it will be possible for passengers to telephone from on board the steamer to any point on the local or long distance lines as soon as the vessel reaches the dock.

A TUBE-ROLLING PLANT with the rolls driven by electric power has just been put in operation at the Etna Works of Spang, Chalfant & Co., near Pittsburg. The motors are direct-connected to the roll shafts and the generating plant has about 750 HP. capacity. Tubes from ½-in. to 8 ins. diameter are made at this plant.

WATER-TUBE BOILERS for British naval vessels are to be investigated by a special commission just appointed by the British Government in response to the numerous published criticisms of the working of the Belleville boilers with which so many of the recent naval vessels have been equipped. The commission will be made up as follows: Vice-Admiral Sir Compton Domville; Mr. List, Superintending Engineer of the Castle Line; Mr. Bain, Superintending Engineer of the Cunard Line; Mr. Milton, Chief Engineer Surveyor of Lloyd's Registry, of Shipping; Prof. A. B. W. Kennedy, Past-President of the Institution of Mechanical Engineers, and one member to be selected. The committee will be instructed, according to our contemporary, "The Engineer," to undertake the following work:

To ascertain practically and experimentally the relative advantages and disadvantages of the Belleville boiler for naval purposes as compared with the cylindrical boiler; to investigate the causes of the defects which have occurred in these boilers and in the machinery of ships fitted with them, and to report how far they are preventable either by modifications of details or by difference of treatment, or how far they are inherent in the system. Also to report generally on the suitability of the propelling and auxiliary machinery fitted in recent war vessels, and to offer any suggestions for improvement, stating at the same time the effect as regards weight and space of any alterations proposed. To report on the advantages and disadvantages of the Niclausse and Babcock and Wilcox boilers compared with the Belleville, as far as the means at the disposal of the committee permit, and also to report whether any other description of boiler has sufficient advantages over the Belleville or the other two types mentioned, as a boiler for large cruisers and battleships, to make it advisable to fit it in any of her Majesty's ships for trial.

STATISTICS OF THE BRITISH TRANSPORT SERVICE during the South African war have recently been issued. The following list shows the number of steamers and their tonnage capacity chartered to convey troops, etc., since July 1, 1899, including ships sailing up to March 31, 1900:

	No. of steamers.	Gross tonnage.
For troops and horses from the United Kingdom and Mediterranean	191	1,171,562
For mules, etc	33	134,754
For troops, horses, etc., from India	49	177,747
For Colonial contingent	29	152,397
For horses from Australia and Argentina	24	101,978
Total	326	1,738,138

The actual number of steamers was 238 and their tonnage 1,230,847; the totals above given including 88 second or third trips of some of the steamers. The total tonnage, 1,738,138 tons, is 65.19% more than the entire steam tonnage of France, and only 421,781 tons less than that of Germany. From the United Kingdom and the Mediterranean 30,101 horses were shipped for the Cape, of which 1,543, or 5.12% were lost. From different ports 31,503 mules were shipped, and 671, or 2.12%, lost. Of 7,344 horses and 1,156 mules sent from India, 1.33% and 25%, respectively, were lost, while of 13,896 horses and cobs dispatched from Australia and Argentina 1.06% were lost on the voyage.

COAL SHIPMENTS FROM THIS COUNTRY to Europe are increasing. It is reported from Philadelphia that 1,000,000 tons have been bought for shipment to France, where there is a great shortage on account of miners' strikes in Germany and Austria.

AMERICAN BESSEMER STEEL is being offered in Sheffield, according to a cable dispatch, dated Aug. 17, at something like £4 per ton below Sheffield-made material, and it is causing a "feeling of unsettledness" in the local trade.

THE NORDBERG PUMPING ENGINE AT WILDWOOD, PA.

(With two-page plate.)

In our issue of May 4, 1899, we gave the results of a test made by Prof. R. C. Carpenter, M. Am. Soc. M. E., upon a pumping engine installed at Wildwood, Pa., for the Pennsylvania Water Co. by the Nordberg Mfg. Co., of Milwaukee, Wis. This engine holds the world's record in efficiency, and, furthermore, was built to meet most exacting conditions in regard to space and arrangement of parts. It is, therefore, worthy of careful study by designers and mechanical engineers. At the annual meeting of the American Society of Mechanical Engineers, held in New York in December, 1899, Prof. R. H. Thurston, of Cornell University, read a paper describing the details of the test above referred to, and gave, besides, a quite complete description of the construction and mode of operation of the engine. The latter part of the paper, slightly abstracted, is presented below. On our inset sheet and in the accompanying cuts are reproduced drawings and photographs which have been furnished us by the manufacturers, showing the design and construction of the machine.

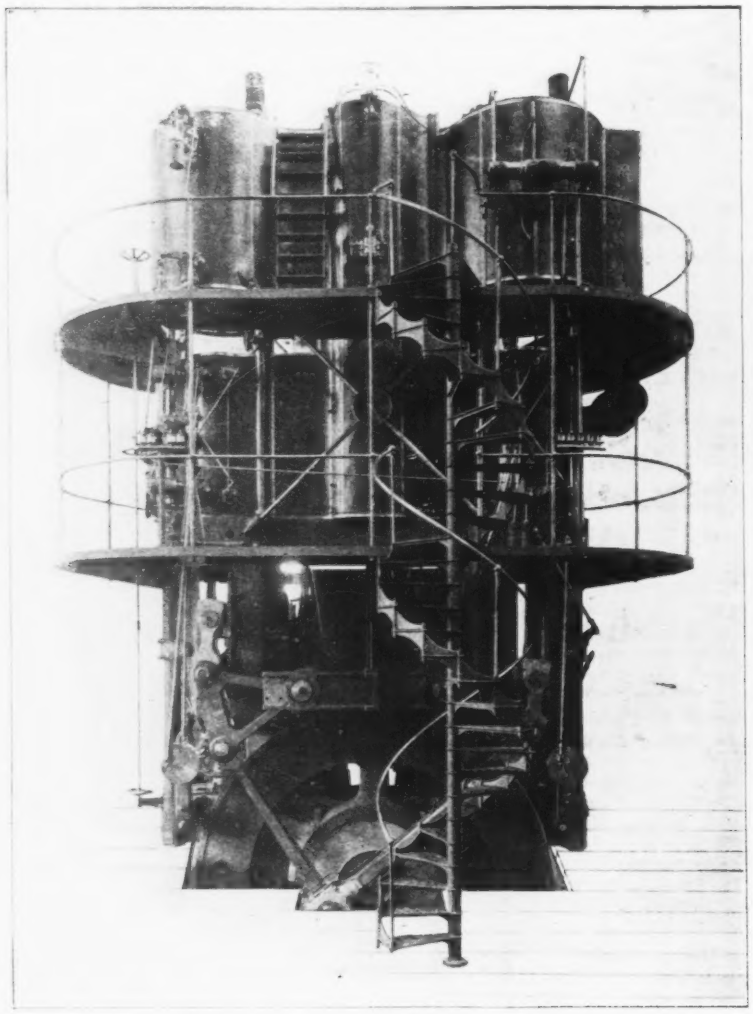


FIG. 1.—FRONT VIEW OF PUMPING ENGINE, BUILT BY NORDBERG MFG. CO., MILWAUKEE, WIS.

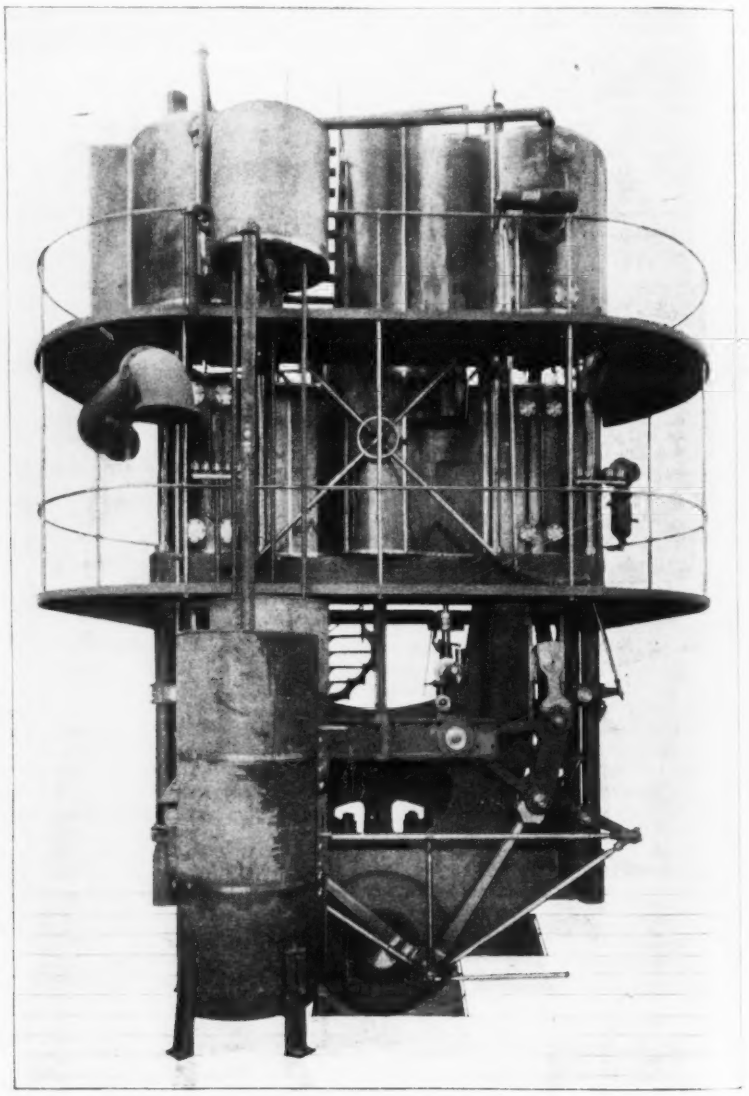


FIG. 2.—REAR VIEW OF PUMPING ENGINE.

The Nordberg engine, about to be described, is a four-cylinder, quadruple-expansion machine, to operate under 200 lbs. steam pressure, and against a head of about 600 ft. between well and reservoir; delivering its water through a rising main of about one mile in length and of 30-in. pipe, taking it from the Allegheny River through a suction pipe 600 ft. long and 24 ins. in diameter. The water pressure at the pumps is thus about 275 lbs., normally. The form of the engine is seen in the accompanying reduced illustrations from photographs taken in the erecting shop, Figs. 1, 2, 3 and 4.

The capacity of this engine is 6,000,000 U. S. gallons per 24 hrs. against a head of 620 ft. The engine is designed to pump water from the Allegheny River, in which the variation of the water-level is very great, nearly 40 ft. between the highest floodmark and extreme low water.

At the Wildwood pumping station there was a well, 38 ft. diameter, which was to be utilized for the new engine, and for two more engines of the same type. It was thus necessary to design an engine to go into minimum space.

The engine, self-contained, rests on a large base-plate, which also serves as a suction air-chamber for the pump. This base-plate rests directly on the country rock, there being no artificial foundation. The water-inlet tunnel, which is 6 ft. in diameter, is led under the center of the well, and from there a suction pipe leads to the middle of the base-plate, a valve being arranged on its top by which the water can be shut off, and a safety valve is arranged on the top of the base-plate to guard against straining this plate in case the pump valves should leak when the water is shut off from the suction; in which case there would be danger of getting the full hydraulic pressure on the base.

The pumps are double acting with outside packed plungers, and rest on the base-plate. The detailed drawing on the inset shows the design of these pumps. Each pump is made in two castings, all four valves being arranged directly in line, one above the other, the plungers being located on one side of the valve chambers. The valves are of rubber, working on brass seats, and arranged in polygonal cages, by which arrangement a minimum diameter of valve chamber is obtained. The drawing shows how the suction and discharge chambers are connected.

In order to guard against breakage of pumps, which in the neighborhood of Pittsburg is quite common, due to the high water pressure and other conditions, the pulsating chambers of the pumps are enveloped in steel casings. The section shows these steel jackets, and the method by which they are fastened to the pumps. It will be seen that there are bolts passing through the pulsating chambers, which serve as anchorage for the plates, or jackets, in question. The jackets are made in halves, and the joint made in the plane passing through the center of the cylinders. Strong set-screws placed in the jackets bear upon the ribs of the pump casting underneath, thus relieving this from the strain due the water pressure. The arrangement is thought to be absolutely safe against breakages.

It is particularly important that the pumps should be very safe in this case, as the engine rests on the pump, and the valve-chamber castings of the pumps are part of the engine framing. It will be seen that the valve chambers are extended on top to receive the engine bedplate, in which is the main bearing, and which supports the engine frame.

A notable and unique feature of this particular engine is that the engine framing is placed in the center of the machine, extending from under the center of the cylinders, downward, with the running parts arranged outside of the framing. There is only one main bearing, extending clear across the engine bedplate. There is a [illegible]-disc on each side of this bearing, on the outside of which are clamped the two flywheels. On each crank-disc is a pin; the two pins being exactly in line.

The plunger rods are directly connected to the steam pistons. At the upper end of these rod connections and immediately below the steam cylinders, are cross-heads keyed to the rods, which cross-heads project sideways outside of the engine frame, and are here formed into pins, which connect, by means of short links, to corresponding pins of the rockers. There are thus four rockers; two on each side of the engine, one driven from each end of cross-heads. Directly in line with the cross-head-pin and its corresponding pin on the rocker, this rocker is provided with a second pin which takes the main connecting rod and connects to the crank-pin. These pins are located in such a position as to bring one side of the engine and one pump on the dead center, while the other side of the engine, with the other pump, is in the middle of its stroke.

Each side of the engine carries two cylinders placed tandem; the high-pressure side the cylinders Nos. 1 and 3, and the low-pressure side the cylinders Nos. 2 and 4.

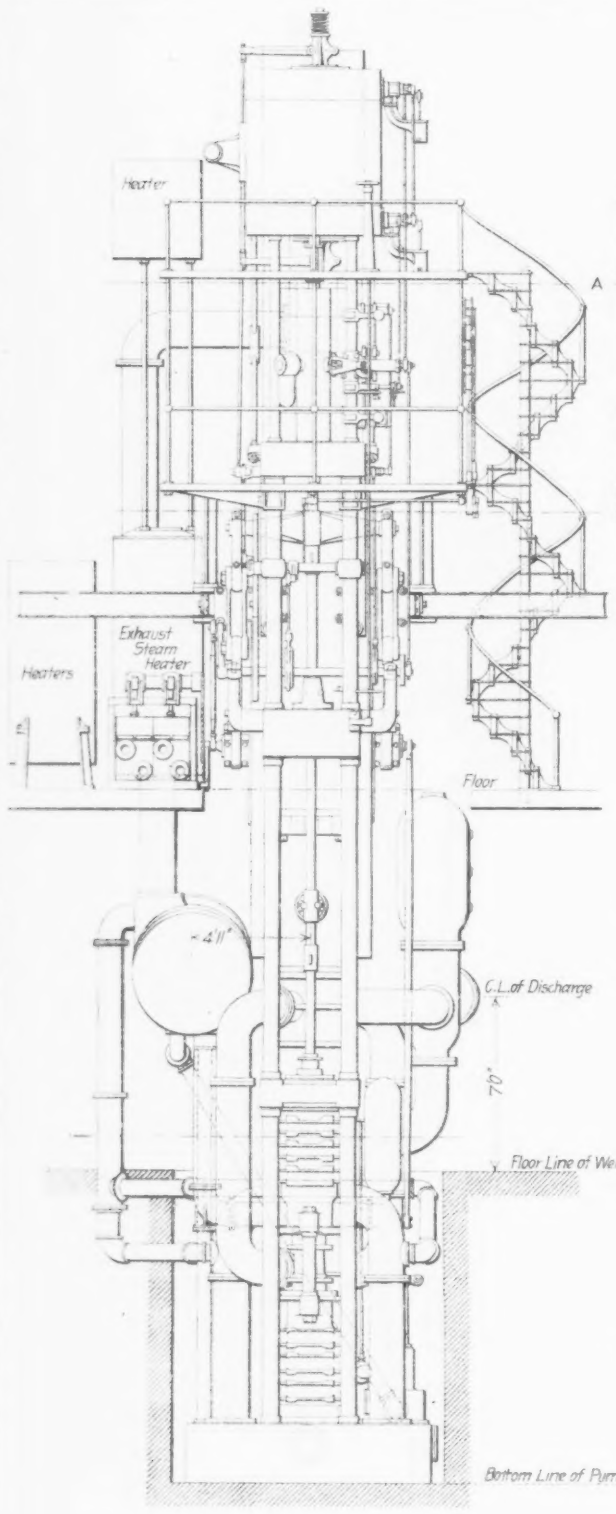
The slides in the cross-head are formed in the engine framing.

The pins on which the rockers are supported are fastened, stationary, in the engine framing, the bearing being formed in the rocker itself.

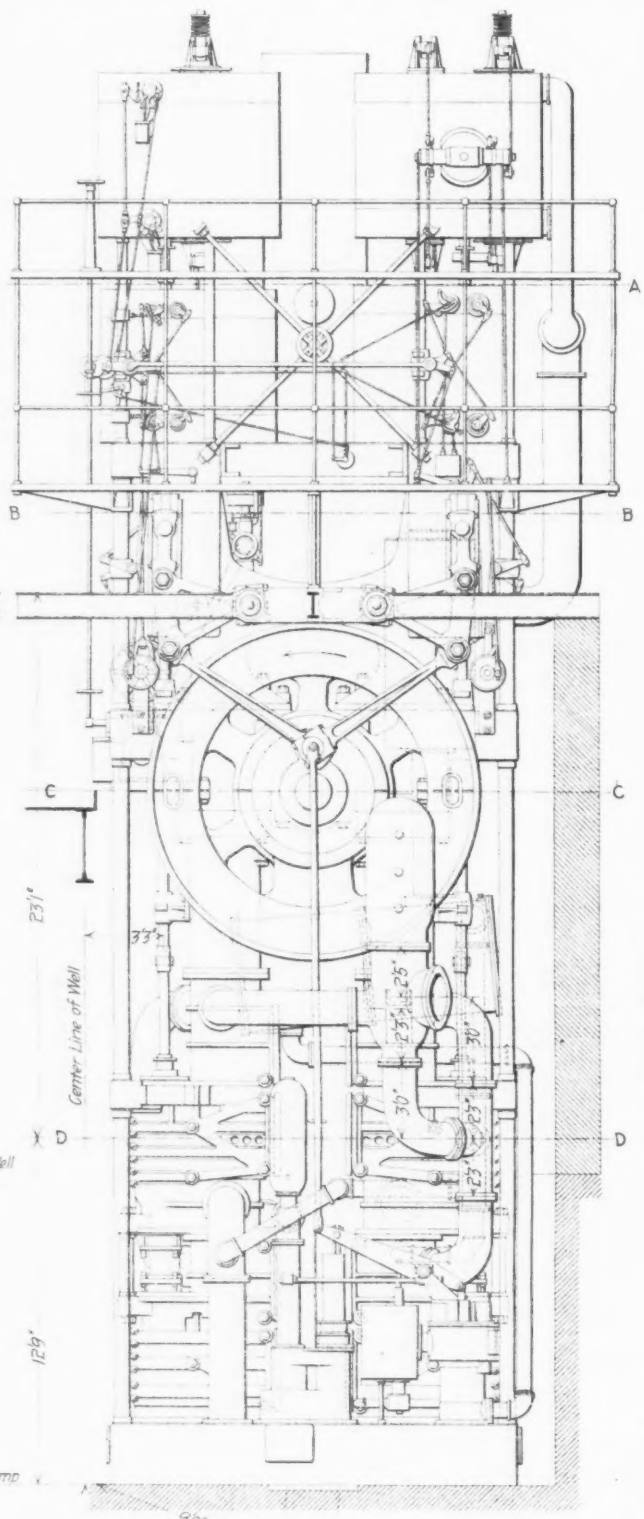
It will be seen from the above that there are two connecting rods attached to each crank-pin; the two connecting rods are in the same plane, and thus one is forked at the crank-pin end, while the other one is single.

The engine frame proper is located inside the piston-rods. In order to get a proper support outside the piston-rods there are on each side two columns extending from the base-plate at the bottom of the machine clear up to the low-pressure cylinders, each column being carried through in an unbroken line. These columns are of cast-iron with a steel tension rod in the center up to the top of the engine framing. From that point upward they are extended by means of polished steel rods.

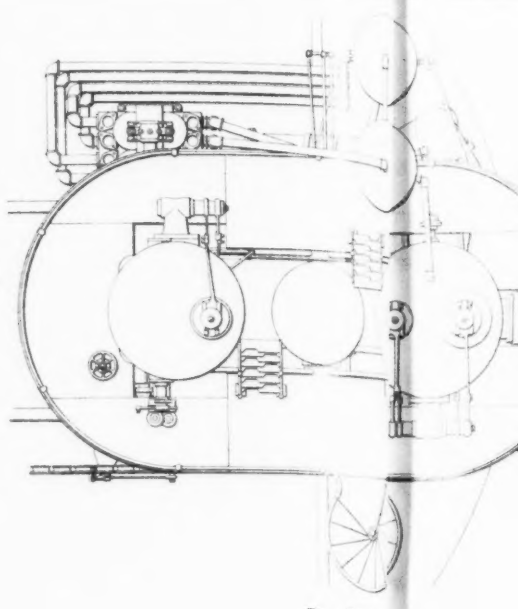
Between the engine frame and the low-pressure cylinders are a second set of polished steel columns on the inside of the center lines of the cylinders, and spaced equally with the outside columns; thus the low-pressure



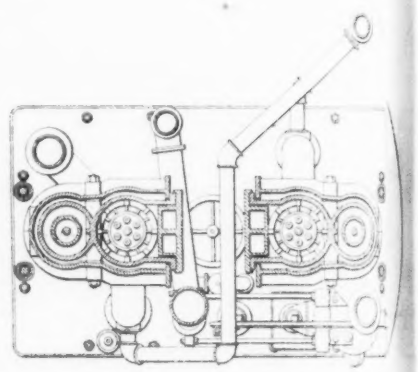
End Elevation.



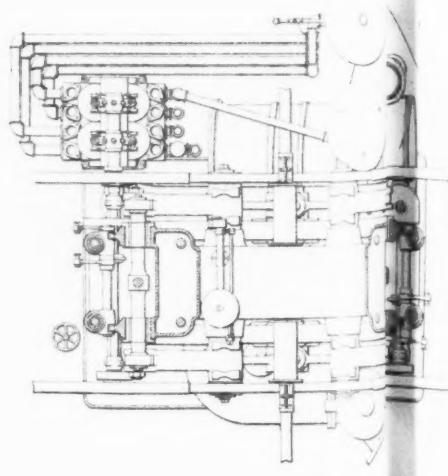
Side Elevation.



Top Plan



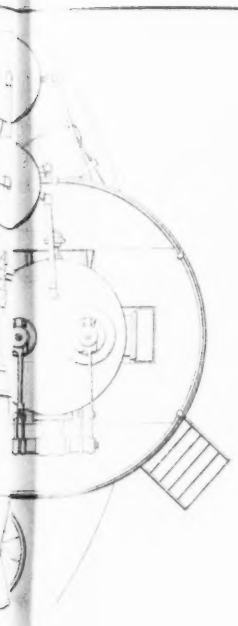
Sectional Plan D-D.

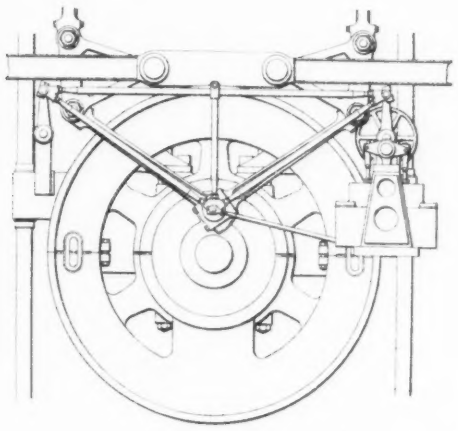


Section Plan

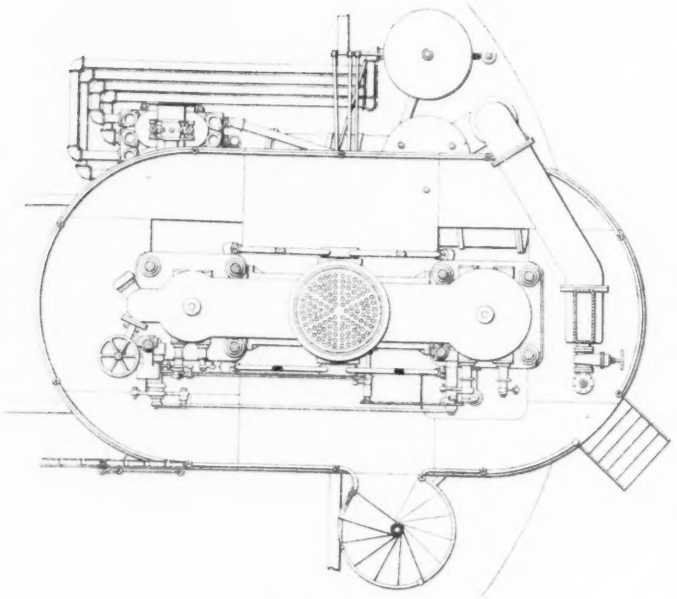
THE 700 H-P. NORDBERG VERTICAL PUMPING ENGIN OF THE P

Nordberg Mfg. Co., Milwaukee, Wis.,

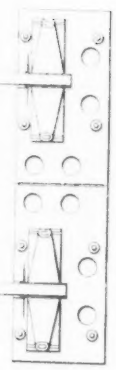


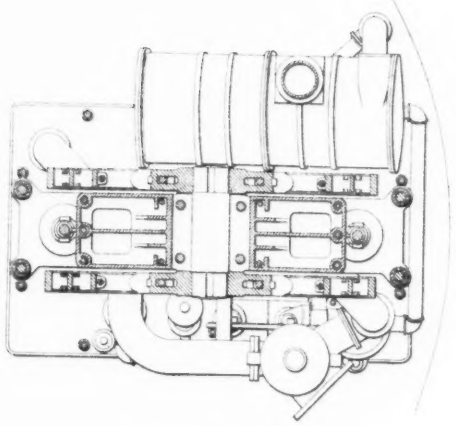


Feed-Pump
and
Valve-Gear Drive.

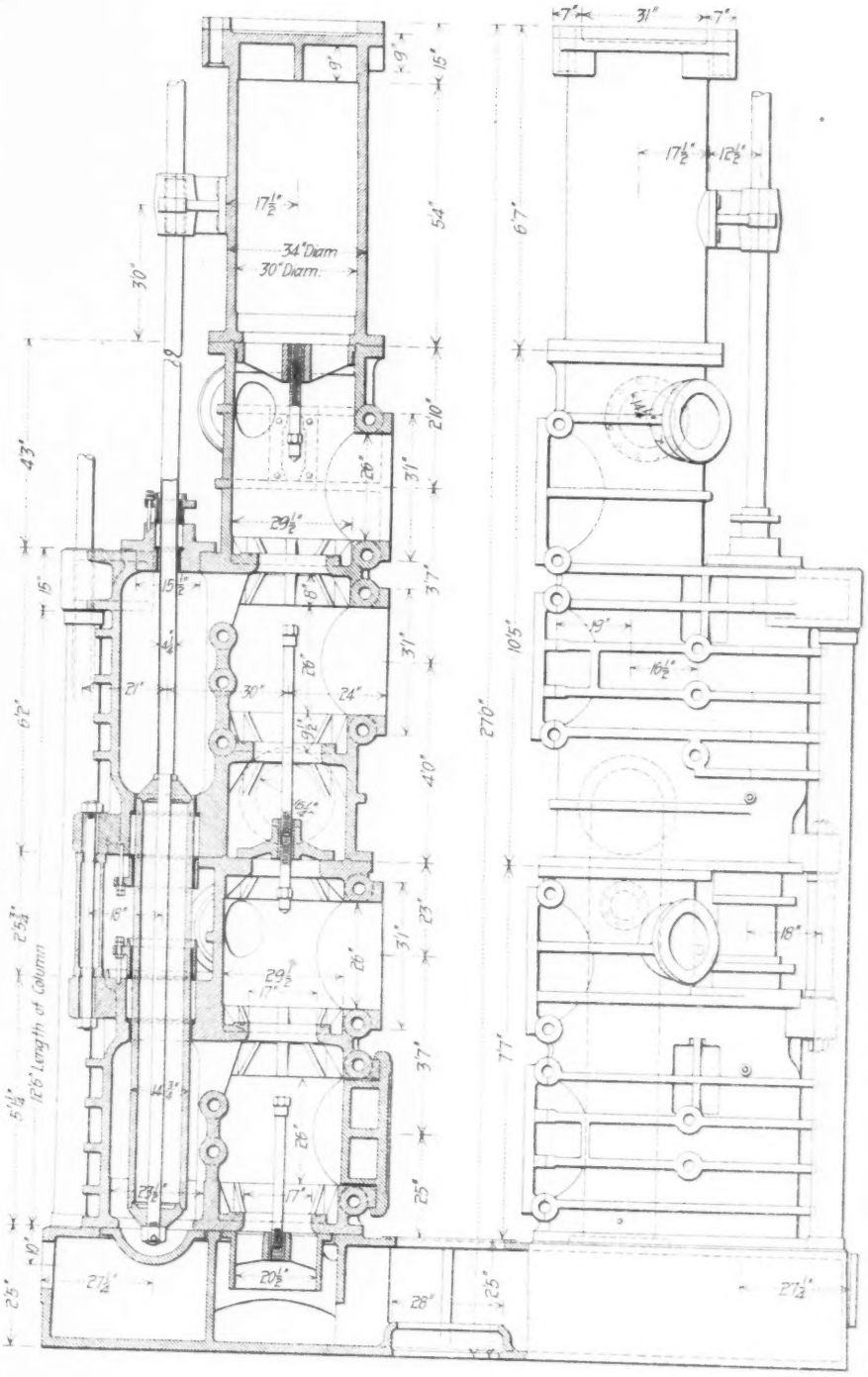


Sectional Plan
A-A.





Sectional Plan C-C.



Sectional Side Elevation
of
14¾ in. x 42 in. Pump.

OF THE PENNSYLVANIA WATER CO., PITTSBURG, PA.

aukee, Wis., Builders.

CHAS. HART, LITH., 98 VESEY ST., N. Y.

cylinders are entirely independent of the high-pressure cylinders, resting on columns of their own. A cross bracing is arranged to give the low-pressure cylinders additional stability.

At the center of rockers the engine is held to side of the pit by means of light bracing.

The receivers are provided with tubular reheaters, as shown on the detailed drawing. These receivers are located between the cylinders, and mounted one upon another in such a manner as to reduce to a minimum the losses caused by radiation.

In order to reduce to a minimum the heat-conduction losses, the high-pressure cylinders are provided with a number of projections, at the bottom ends, which rest upon the framing, and leave quite a space between the body of

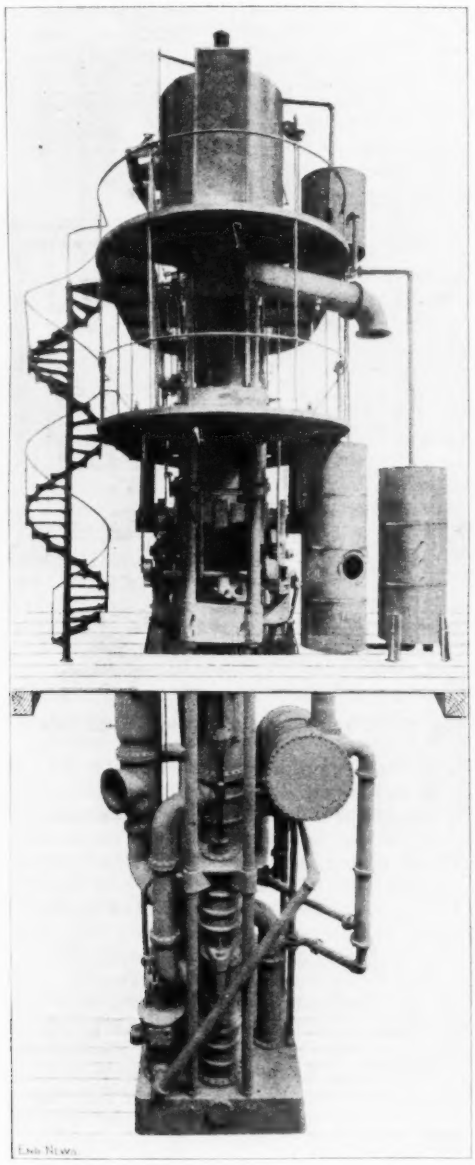


Fig. 3.—End View of Engine and Pump.

the cylinder heads and the frame, which is filled out with non-conducting material; the only surface in contact with the cylinder and frame being the small surface of these projections, or bosses.

All cylinders are steam jacketed on the barrels only, the high-pressure cylinders being provided with separate liners; the low-pressure cylinders having the jackets formed in one casting with the cylinders. The valve gear is of the Corliss type, with the exception of the No. 4 cylinder valves, and the exhaust valve gear on No. 3 cylinder, in which single-beat poppet valves are used in order to reduce clearance to a minimum. The cut-off is variable on all cylinders, except on No. 4; the high-pressure cut-off being under control of a centrifugal governor. As the cylinder ratio between No. 2 and No. 1 cylinder is comparatively small, and a low degree of expansion is carried in the high-pressure cylinders, a special valve gear had to be used in these cylinders, by which steam can be cut off after half-stroke. The ratio between No. 3 and No. 2 cylinders is so great that steam can be cut off before half-stroke, and an ordinary Corliss gear was used on this cylinder. The ratio between No. 4 and No. 3 is small; steam in No. 4 had to be cut off at about three-quarters, thus requiring no special cut-off mechanism, or drop releasing gear.

The valves are operated from two revolving lay-shafts, one on each side of the machine. With the construction of the crank-shaft it was not easy to arrange eccentrics on this shaft, from which to operate the valve gears. A rotating gear, as illustrated in the drawing marked "Feed Pump and Valve Gear Drive," was therefore used to transmit the rotation of the crank-shaft to the lay-shafts. From one of the lay-shafts the governor is driven by a belt.

A surface-condenser was used in connection with this engine. This condenser had to be located so high that at times of low water the main pump could not be depended on for circulation unless the full water pressure was carried on the condensers, which would not be advisable. A circulating pump was therefore used which takes the water from the suction base and elevates it into the condenser. The circulating water from the condenser is returned to the suction through two branches, one entering each pump. It was thought best to do this instead of letting all the water come back to one point; although there might not be much advantage in doing it. The end view and section DD of the machine shows this pipe. The surface condenser is very much like those used in marine practice. The water passes through the condenser three times, entering at the bottom and leaving at the top. It is the practice of the designer to incline all surface condensers, as the water of condensation has a better chance to run off. The tubes are ¾-in. in diameter, held in place by vulcanized fiber bushings.

Mr. George H. Corliss probably originated the vertical air pump without foot valve; this is the type of air pump used with the Wildwood engine. The discharge from the air pump runs into a tank, from which it is elevated by means of a separate pump into a high-level tank.

The circulating pump, the air pump, and the tank pump are all operated by means of a lever-and-rod connection from the crank-shaft of the engine, as shown in side elevation of the engine.

The pumps used with the heaters require special description. All builders have found it difficult to get a pump for hot water, and in this case a special design was made to handle water of a temperature above 300° F. The sketch (Fig. 5) shows the principle of the feed pumps, as designed, which pumps have given perfect satisfaction.

Fig. 5 shows the principle of construction. A is the plunger, BB the suction and discharge valves, C the suction nozzle, and D the discharge nozzle. The pump is single acting. A hood F is placed above the plunger A the plunger rod G projecting through the upper end of the hood, in which is formed a stuffing-box H. An annular chamber I is formed around the main stuffing-box J, which communicates with the suction nozzle by a pipe connection L and a check valve, which opens when the pressure in space I exceeds the pressure in suction pipe. The main stuffing-box is packed with duck-packing, the stuffing-box H with metallic piston-rod packing. The pressure in the suction pipe C is about the same as in the receivers by which the different heaters are supplied with steam. The leakage through the packing in the stuffing-box J is caught in the space inside of the hood F, and the water runs thence through openings V into an-

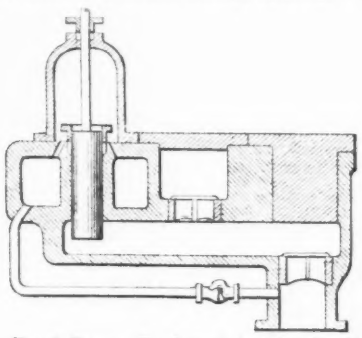


Fig. 5.—Feed Pump Designed to Handle Water at High Temperatures.

nulus I. The steam fills the space E inside of the hood, and stuffing-box H is thus never in contact with water but with steam. Whenever the pressure in space E and in annulus I exceeds the pressure in suction pipe C, the check valve opens and discharges the water into the suction pipe. By virtue of this arrangement the pressure in E and I is always equal to the suction pressure.

Leading Dimensions of Engine.

No. 1. Cylinder	19½ ins.
No. 2. Cylinder	29½ ins.
No. 3. Cylinder	49½ ins.
No. 4. Cylinder	57½ ins.
Plungers	14¾ ins.
Stroke of steam pistons and plungers	42 ins.
Main bearing	18 × 37½ ins.
Crank-pins	7½ × 12½ ins.
Cross-head pins	6 ins. diameter × 5 ins. long.
Pins in rockers	6 × 5 ins.
Main trunnion for rockers	9⅞ × 22 ins.
Low-pressure piston-rods	3⅝ ins. diameter
High-pressure piston-rods	4⅞ ins. diameter
Pump rods	4½ ins. diameter
Feed pumps. Single acting	6 ins. diameter × 8 ins. stroke
Air pump. Single acting	20 ins. diameter × 14½ ins. stroke
Circulating pump differential	15⅝ bucket, 10⅞ plunger × 34½ ins. stroke
Tank pump	5 ins. × 9¼ single acting
Reheating surface; 1st receiver	139 sq. ft.
2d receiver	139 sq. ft.
3d receiver	139 sq. ft.
Condenser surface	1,500 sq. ft.
Suction pipe	24 ins. diameter
Discharge pipe	24 ins. diameter

The contract presented an unusually interesting and exacting problem in design. It was required to provide for three distinct machines in a single pit, which was but 38 ft. in diameter, and this compelled the reduction of the diameter of the steam cylinder to a minimum, and the adoption of as high a piston speed as was safe. This accounts, in part, for the fact that the ratio of expansion was made less than is often observed in engines of this class, and it is thought by the designer that the results do not represent the highest duty to be expected of quadruple-expansion engines of this type, although the peculiar cycle adopted makes this ratio a matter of less importance.

The system of regenerators employed (Fig. 6) was novel, and had not been before constructed by the designer; his idea being, in this matter, to secure such a system as

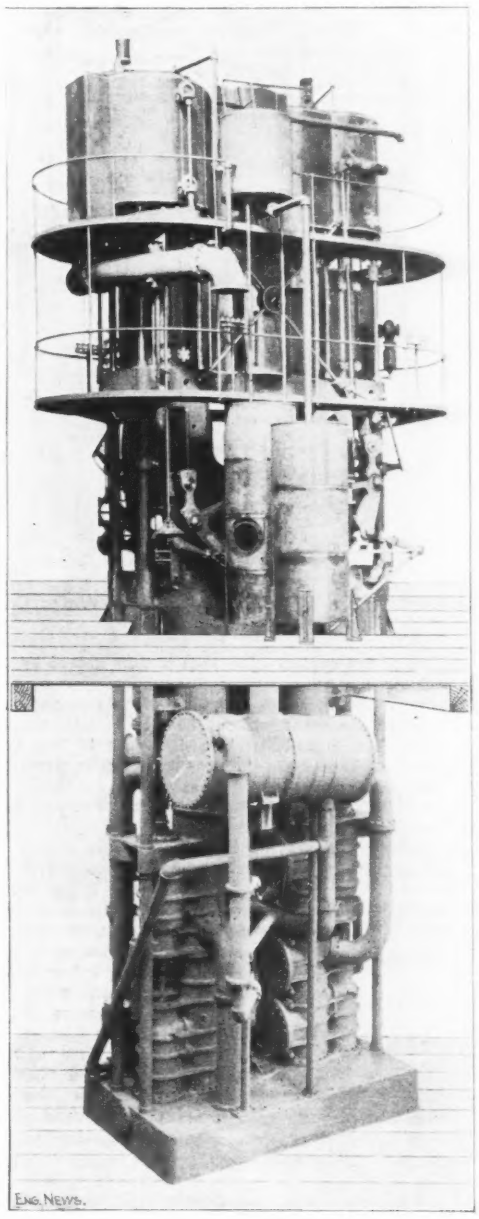


Fig. 4.—View Showing Pumps and Heater System.

would permit the economical use of the highest steam pressures that may prove safe in any case, returning the feed-water to the boiler at very nearly the temperature of the steam itself. Such attempts as had been previously made by him in earlier engines, to approximate this condition, had, however, proved very satisfactory, as may be seen by consultation of the reports of Chief Engineer Perry, U. S. N., on the U St. engine at Washington, D. C., published in London "Engineering," and that of Prof. M. E. Cooley on the Grand Rapids engine by the same builders. These were triple-expansion engines. In the trials of all engines of this type it is evident that the necessary interruption of the heat cycle in the measurement of the feed-water must involve a loss of efficiency, of which loss only estimates can be made; although it should usually be possible to secure a very close approximation.

The heat distribution of this engine is best shown by the use of the "Sankey Diagram," of which a reproduction, for this case, is given in Fig. 7. The heat supplied by the boilers, reckoned at 100%, meets at A 30.7% of its own amount returned from the feed-heating system, distributes 15.6% to the jackets, and the balance to steam cylinder I. Transformed energy passes out of the system at C as work, of which less than 7% is lost as friction and is reconverted into heat and dissipated. 75% is sent,

at D, into the condenser, and the curious system of heating and of adheating feed-water uses a part of this, and much more, from the various jackets and receivers, in a manner readily traced on the diagram, so as to produce, in some degree, that transfer of heat from the expansion to the compression side of the type diagram which has been already described as the ideal substitute of Cotterill for the Stirling equivalent of the Carnot system, and as indicated in the description, just given, of

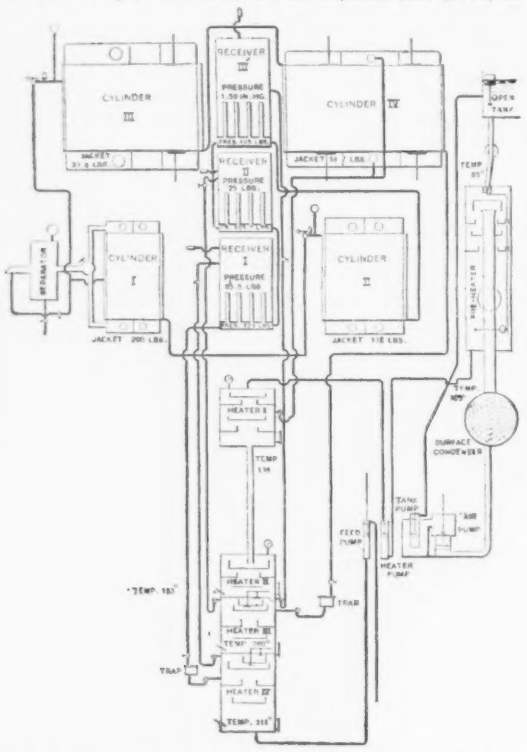


Fig. 6.—Diagram Showing Steam and Water Connections.

the action of the engine. The heat is thus gained by the feed at increasing temperatures throughout.

The combined indicator diagrams of this engine, the one with and the other without heaters in use, are exhibited in Figs. 8 and 9. The difference is less than would perhaps have been anticipated; but it is nevertheless a very observable one. The saturation curves of the series of cylinders is discontinuous in the first and very nearly continuous in the second case; showing the effect of the heaters in improving the action of the engine, by reducing the amount of steam taken into each cylinder for equal powers, and by increasing the completeness of re-evaporation during the progress of the stroke of the piston. It is also observable that the quantity of steam taken into each successive cylinder is less by the amount of steam taken out for use in the heaters. Without heaters, the saturation line runs smoothly from end to end of the combined diagram, illustrating, further, the admirable proportion of these elements, in series, which has been secured by the designer. The success met with in the endeavor to secure small clearances is well exhibited in these diagrams; as is also the depression of the back-pressure line, throughout the whole period of the return stroke. The loss of work between cylinders is an unusually small proportion of the total area of the diagram, and the waste by rounding off of corners is less than is common in this class of engine. In this, also, as in almost all other engines making a record for economy and high duty, the terminal pressure is brought down to a comparatively low figure, here about 8 lbs. per sq. in. absolute, and rarely less than 7 or higher than 10, with the now usual high boiler pressures, approximating 200 lbs.

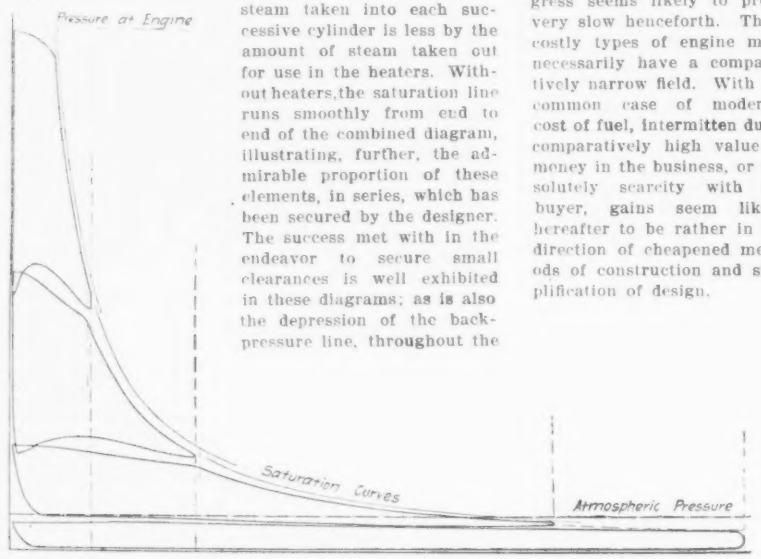


FIG. 8.—COMBINED INDICATOR CARDS, WITH HEATERS.

Table showing Performance of the Best Engines of the Present Time.

	I. HP.	Steam pressure.	Speed of piston, Ft. per minute.	Per I. H. P. per hour. Pounds	B. T. U.	Foot-pounds duty per 1,000,000 B. T. U.
Simple Engines.						
Sulzer	284	87	372	18.4	20,250	88,000,000
Corliss	137	62	...	17.5	19,250	92,630,000
Compound.						
Dujardin ..	548	90	570	13.46	14,800	120,400,000
Sulzer	247	85	493	13.35	14,700	121,100,000
Wheelock ..	590	160	612	12.84	14,100	126,400,000
McIntosh & Seymour.	1,076	125	800	12.76	13,000	137,000,000
Leavitt	643	135	371	12.16	13,400	133,000,000
Triple Expansion.						
Sulzer	615	141	516	11.85	13,000	137,000,000
Reynolds ..	574	120	203	11.68	13,056	140,817,000
Leavitt	576	185	240	11.22	12,242	141,855,000
Snow	773	156	215	11.26	.....	150,100,000
Allis	801	187	192.5	10.34	11,764	157,002,500
Quadruple.						
Hall & Treat.	16	300 / 400 / 500	220	10.80 / 9.65 / 9.75	13,500	132,000,000
Nordberg ..	712	200	250	12.26	11,158	162,948,824

In studying these diagrams, it will be remembered that the saturation curve is that with which the expansion line of the diagram would have coincided, had the expanding steam been retained in the dry and saturated state.

In all cases so far, records have been made on a basis which, directly or indirectly, rates the machine by its physical efficiency; while the true basis must ultimately be recognized as being work performed per unit of cost, including operating expenses, interest on investment, and of maintenance and replacement accounts. The basis here accepted is a measure of the perfection of the design, construction, and operation; the commercial basis involves, with this, the success of the responsible financial officer in making investments in the steam plant add to the dividend-paying capacity of the establishment of which it forms a part. This latter ultimate and basic requirement compels the designer to conform his work to the demands of the finance of the case, and forces him to proportion his steam plant for a lower expansion ratio, a lesser duty, and considerably reduced costs of construction. Thus it may be found that, in a representative case, the reduction of the expansion ratio to about seven-tenths its figure for maximum duty, and the resultant reduction of that duty to about seven-eighths the maximum, may prove commercially and financially advantageous.

Just how far the use of this system should be affected by costs of construction, and how far commercial efficiency would be affected by changes of proportion and design, remains to be determined.

The steam engine has now been so far perfected, and the practical limits of pressure are coming to be so nearly approached by steam-boiler constructors and users, that but little more can be expected of the designer; and, even with the costlier types of engine, practically justifiable with exceptionally high costs of fuel, uninterrupted working and low values of money, as in some instances with the steam pumping engine, commercially practicable progress seems likely to prove very slow henceforth. These costly types of engine must necessarily have a comparatively narrow field. With the common case of moderate cost of fuel, intermitten duty, comparatively high value of money in the business, or absolutely scarcity with the buyer, gains seem likely hereafter to be rather in the direction of cheapened methods of construction and simplification of design.

SPANISH TRADE WITH THE UNITED STATES was larger in the fiscal year just closed than in any year since 1893. We exported to Spain $13,400,000 worth of goods and bought from her nearly $6,000,000 worth in return. Our exports to her were chiefly raw cotton, breadstuffs, mineral oils and woodenware, and in imports, fruits, nuts and wines form the largest items, although $645,000 worth of Spanish iron ore came to the United States in the year ending June 30, 1900.

THE SYSTEMATIC LOCATION OF PIPES AND WIRES IN THE STREETS AS OPPOSED TO SUBWAYS.

At the recent meeting of the Western Gas Association a paper was read by Mr. Donald McDonald, of Louisville, Ky., in which he advocated the location of gas, water, sewer and other pipes and various electrical wires in accordance with some well-conceived plan, rather than the placing

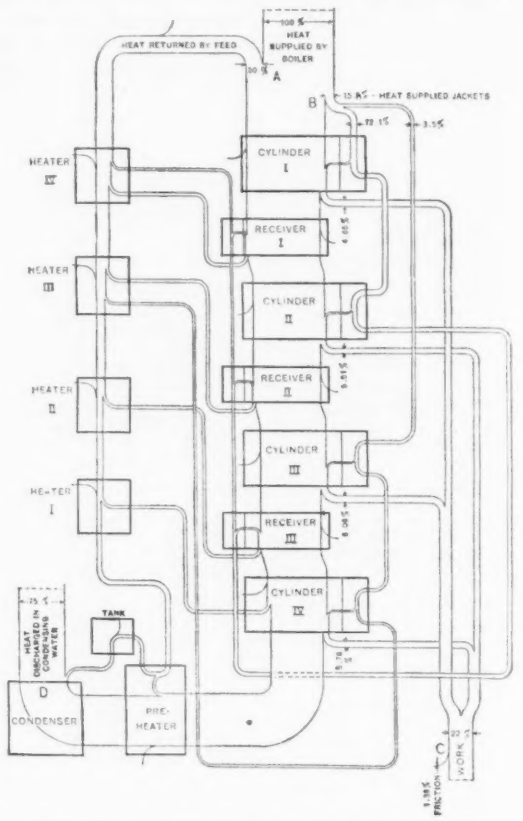


Fig. 7.—Diagram Showing Heat Distribution.

of such underground conduits in subways. The plan is well worth considering, but not so much as a substitute for subways as a common-sense method, to be followed wherever subways, for whatever reason, are not being and not likely to be constructed. In fact, so little has been done or proposed in the line of general subway construction that there is an open field for carrying out the suggestions of Mr. McDonald wherever pipes and wires are being laid or relaid.

The first proposition is that cities and towns adopt ordinances to the effect that on all new streets, and as far as possible on new construction or reconstruction in old streets, all pipes and wires running north and south be laid say 2 ft. beneath the surface, and those running east and west 4 ft., the exact depth to vary with the frost lines. Gas pipes he would have placed 2 ft. from the curb; water pipes, 3 ft, and so on.

A second, and very important, proposition is that all pipe connections, particularly services, shall be at the tops or bottoms of the mains, instead of the sides, since it is proposed to place all pipes and conduits in practically the same horizontal plane. The various service pipes for each house, or for a group of houses, would be carried to the curb line in a common trench, provided with a removable iron cover to give access to the services without digging.

The chief advantages claimed for this system are economy and diminished interruption to traffic, both in first cost and repairs, through lessening the depth of street excavations. In the case of services, the only disturbances to the

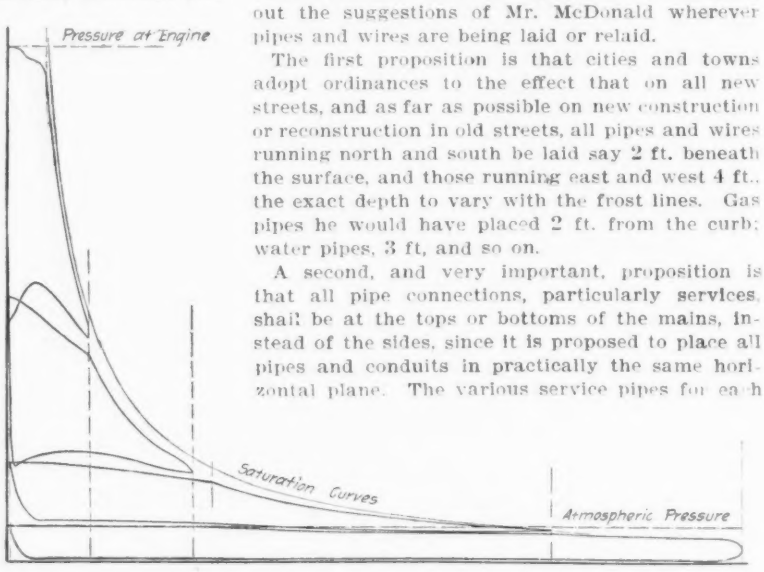


FIG. 9.—COMBINED INDICATOR CARDS. WITHOUT HEATERS.

street, once the services are laid, would be that due to the removal of plates.

Subways, the author held, would often be rendered almost impracticable if sewers were to be included, owing to the great depths often necessary for sewers, the dangers of water leaking into telephone cables and of leaks in gas mains, causing explosions. If sewers were omitted from subways he still saw many obstacles to their use, including the great size and cost required to contain the many pipes and wires now in demand and in prospect, and the more rapid deterioration of pipes in the damp air of the subway than those placed in the earth.

In discussing the paper, Mr. Moyers, of Columbus, O., said he did not believe the public would tolerate the iron covers for the service pipe conduits every 100 ft. or so, nor that such conduits would be worth their cost, nor that they would be practicable, owing to the freezing in gas and water pipes. He disapproved having gas and water pipes in the same trench, as a general proposition, stating that if both leaked the gas main would soon be filled with water. The paper and discussion in full will be found in the "American Gas Light Journal" for June 11, 1900.

THE IMPROVEMENT OF THE SOUTH PASS OF THE MISSISSIPPI RIVER.

By William Starling, M. Am. Soc. C. E., M. Inst. C. E.*

The Mouths of the Mississippi.

It is well known that the Mississippi makes its way to the Gulf through three great branches or passes (Fig. 1). On the extreme left, to the east, lies Pass a l'Outre, about 14.5 miles in length, to the land's end. In the middle lies South Pass, which, before its improvement, was about 12 miles long. On the right, to the west, is Southwest Pass, about 17 miles to the land's end, or 20.25 miles to the outer crest of the bar. All distances are measured from the head of the passes, or the place where the axes of the three passes intersect.

Pass a l'Outre, about five miles from the common head of the passes, puts forth a branch to the right called Southeast Pass; and at about 12 miles a short branch to the left called North Pass. Southeast Pass, at about 10 miles from the head of the passes, splits into Northeast and Southeast Passes, of which the former is the greater. South Pass, before its improvement, had a branch named Grand Bayou, on the right, about half way of its length. Southwest Pass has no branches.

Pass a l'Outre is the largest of the passes, and South Pass is the smallest. In 1878, during the construction of the jetties, the proportion between the discharges of the passes was about 46, 43 and 11. It is probable that this proportion was somewhat changed by the execution of the contraction works which were put in from time to time, which reduced materially the cross-section of the jetties and of South Pass itself. It was still further changed by the occurrence of a crevasse or break in the right bank of Pass a l'Outre, about a mile and a half below the head of the passes. This opening increased the discharge through Pass a l'Outre at the expense of the other passes, so that at the present day it is estimated that about 50% of the volume of water which reaches the head of the passes empties into the Gulf by way of Pass a l'Outre. About 41% makes its exit through Southwest Pass and about 9% pours out through South Pass. The banks of all the passes are very low.

The general sinking of the level of the Gulf Coast, from the Rio Grande to Florida, is supposed to amount to about 2 ft. in a century. At the mouth of the Mississippi it is far more. At Port Eads, at the landward end of the jetties of South Pass, it is at the rate of about 1 ft. in 19 years, or say 5 ft. in a century. The banks of the passes, however, are not depressed below the sea level by this movement. They are liable to overflow in high stages of the river when the waters of the latter are most heavily charged with sediment. A portion of the earthy matter held in suspension is deposited upon the banks; and by this process the banks are kept up nearly to high-

*Member of the Southwest Pass Board, New Orleans, La.

water level. Of course, they can never reach this level; for an increase of height can only be attained by deposit from water which overflows it. What external forces there are tend to depression.

The range or oscillation caused by the alternation of high and low water in the river, independent of the tides, is something like 2 ft. At New Orleans it is about 20 ft.; at the Forts about 6 ft.; at the seaward end of the passes it is almost imperceptible. It is something, for it is enough to confer a velocity, over the bar outside the mouth, of 4 ft. or more per second at high water of the river; whereas at low water the current is only 1 ft. a second or so even at ebb tide, and almost null during flood.

The passes do not carry all the high-water or even the low-water flow of the Mississippi At extreme high water, a considerable proportion of the total discharge of the river does not even pass

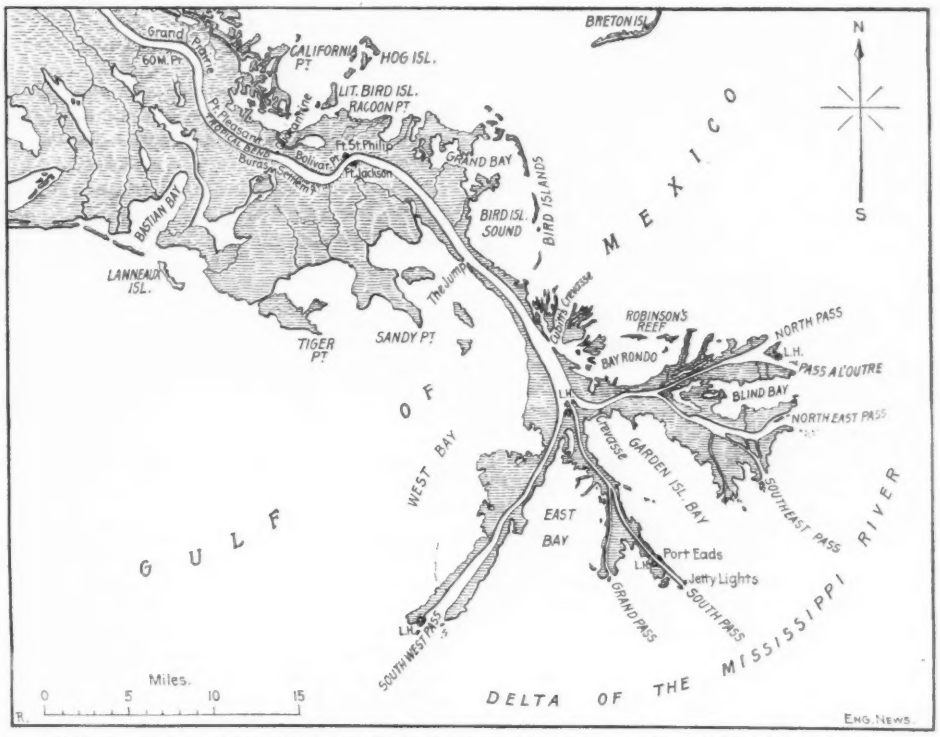


FIG. 1.—MAP SHOWING THE DELTA AND PASSES OF THE MISSISSIPPI RIVER.

by New Orleans, but goes out, directly or indirectly, through the Atchafalaya; directly, by way of Red River; indirectly, through crevasses in the levees along the right bank. Sometimes also a part of the discharge is carried off through breaks in the levees of the left bank, through Lake Maurepas and Lake Pontchartrain. In 1897, out of a total discharge at Vicksburg of perhaps 1,750,000 cu. ft. per second, only about 1,500,000 cu. ft. passed in the channel of the river, the rest being lost through crevasses; and only about 1,300,000 cu. ft. passed New Orleans, the remainder being diverted, in one way or another, through the Atchafalaya.

Even of the water which passes New Orleans, however, not all goes out through the three great branches which have been named. The levee system ends a little below the Forts, about 76 miles below New Orleans and 20 miles above the head of the passes; and in great floods there is a noticeable outflow over the banks. In addition to this source of leakage, there are several well-defined outlets between the Forts and the passes. About 8 miles below the Forts, on the left bank, is Baptiste Collet's Canal, an artificial opening made for the convenience of the oystermen, which, inconsiderable at first, is said to be enlarging with rapidity. Hitherto it has not played any important part. One mile below this opening, on the other side of the river, is another called The Jump, about 450 ft. wide and 43 ft. deep near the river end; seven miles farther down, and four miles above the head of the passes, is a much larger and more important outlet, which is known by the name of Cubitt's Gap. This, in 1898, was 3,240 ft. wide, and carried 155,600 cu. ft. of water a second during the high water of that year, which was not a great one. The Jump, at the same time, carried 35,080 cu. ft.

First Attempts at Dredging.

Neither Pass a l'Outre nor Southwest Pass, in its natural state, afforded anything like an adequate depth for vessels of even moderate size. South Pass was even worse. The obstruction was not in the passes themselves, but at their mouths, or rather outside their mouths, where there were formidable bars, with a depth on their crests of only 7 to 13 ft. Consequently, various projects were suggested; but the only means which met with any success was stirring up the material of the bar with powerful cutters and letting the silty earth thus dislodged float out to sea. It is evident that such an expedient could be successful only when there was a strong seaward current. Consequently, the boats could be employed for but a part of the year. Between storms, breakages, repairs and slack currents, the boats made an average of only about 100 working days in the year. They were operated for 10 hours a day. Even under these unfavorable circumstances they succeeded in establishing and maintaining a navigable channel varying from 16 to 18 or 19 ft., and with a somewhat uncertain width of from 100 to 250 ft.

The boats designed for the "stirring up" process were powerful vessels, built for this express purpose. The first, the "Essayons," was designed by Major McAlester, and was completed in 1869, at a cost of $223,000. The agency by which the loosening of the material of the bar was effected consisted of propeller-blades extending below the keel. An improvement was added to this apparatus by Major Howell, in the form of a "deflector," which more effectively directed the disintegrated material into the upper currents. In 1871 a contract was made for the construction of a still more powerful vessel, which was named the "McAlester," in honor of the designer of the "Essayons," who had lately died. With these two boats work was kept up until the latter part of the year 1877, when it was discontinued upon official notification that 20 ft. had been secured and preserved through South Pass.

The Construction of Jetties.

The history of the improvement of the South Pass is important in many ways. As a successful attempt to create a deep navigable channel at the mouth of a great silt-bearing river, it is well worthy of study. It is especially interesting at the present time in view of the projected and, it may be hoped, approaching improvement of Southwest Pass, to which it affords the closest existing parallel.

Many of the conditions are nearly or quite similar, and the lessons derived from the experience of Mr. Eads and his associates and successors are

in large part applicable to the newer and greater project. They are full of instruction and of warning. The early history of the improvement of South Pass is given with all requisite particularity by Mr. Corthell in his well-known work,* and is, therefore, easily accessible. This account, however, comes down only to 1880. The twenty years intervening between that date and the present have brought about great modifications in the jetties themselves, in the general course of the pass above and in the Gulf beyond the mouth of the pass. It may be said with truth that in this period is contained the most interesting and most instructive part of the history of the improvement. Fortunately there is abundant material for the compilation of such a history in the reports of Mr. Cornelius Donovan, M. Am. Soc. C. E., U. S. Assistant Engineer, who has had charge of this work for about 22 years, and these reports are to be found in the Annual Reports of the Chief of Engineers.

The details of the construction of the jetties are of no special interest at this day, when the type is no longer a novelty. Briefly, each pier consisted of a number of tiers of willow mattresses 2 ft. thick, each tier being weighted with stone enough to sink it. The foundation mattresses were from 35 to 50 ft. wide, and from 75 to 100 ft. long. The top tier was 25 ft. wide. The whole structure was capped with rip-rap, or random stone—the uppermost course of which was composed of heavy stone laid by hand. Later on, both jetties were surmounted by a course of concrete blocks, built in place, for a great part of their length—the East Jetty from station 65 and the West Jetty from station 90, respectively, to the sea ends. The blocks varied from 3.5 ft. wide, 3 ft. thick and 16 ft. long, at the landward end, to 13 ft. wide; 5 ft. thick and 55 ft. long at the seaward end. The heaviest blocks weighed more than 260 tons. A continuous parapet was built on the blocks of the East Jetty, mostly consisting of concrete, but partly of concrete rubble masonry. The top of the parapet was 5 ft. above average flood tide. Landward of the concrete work, on both jetties, the capping was of heavy rubble stone, rounded into a crown, the grade of which was 1.5 ft. above datum (average flood tide).†

It was found that the construction of the parapet "generated new wave forces, which the rubble stone or even the dimension rock could not withstand. The waves which previously swept over the jetties and expended their force by the concrete blocks were converted into racers, which, in storms, swept along the jetty with terrific force, picking up the rock which lay upon the slopes, scattering it in every direction, where an obstruction opposed its further course, piling up the rock upon it, and at times hurling them over the concrete blocks. To prevent this action of the waves, which, if continued any length of time, would undermine the jetties, spur cribs were built and placed about 100 ft. apart, on both sides of the jetties, wherever they were exposed to the racers. These cribs were loaded with rubble stone. The crib-work for protecting the ends of the jetties was constructed of palmetto logs. The wood of the palmetto is very fibrous, tough and corky, and it resists the action of the teredo. It weighs about 40 lbs. to the cu. ft."

The treatment of the sea ends of the jetties was an interesting problem. The end of the West Jetty was closed entirely by crib-work for a distance of about 300 ft. The end of the East Jetty, being the more exposed, was still more strongly fortified against storms and currents. It was given a very flat slope on both the Gulf and river sides, being capped with heavy rubble stone, with the usual concrete parapet. Later, it also was surrounded by an elaborate arrangement of crib-work. The following sketch, Fig. 2, was somewhat hastily made from a drawing in the possession of Mr. Ubsdell, the representative of the Eads estate resident at Port Eads. It shows the crib-work around both pier-heads.

The cribs were carried much farther up the channel than is shown by the sketch. The mattresses, by virtue of their own weight, of the silt which had infiltrated the interstices between the willows and the stone which weighted them, became considerably compressed, especially near the sea ends; so that in many places the crown had sunk 2 or 3 ft. below the level of the water. These losses had to be made good by various ingenious expedients, which need not be described here.

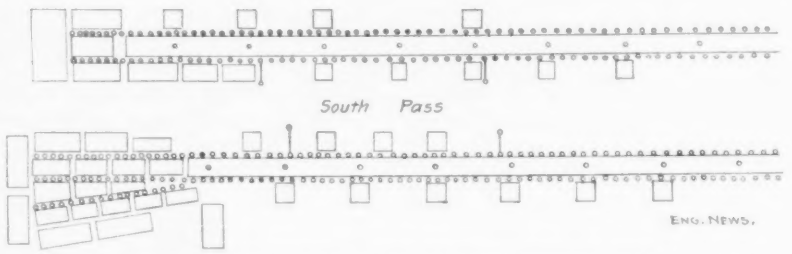


FIG. 2.—SKETCH SHOWING METHOD OF PROTECTING THE ENDS OF THE JETTIES BY CRIBWORK.

Early Difficulties with the Working of the Jetties.

At a very early stage of the construction of the jetties (April-June, 1876), less than a year from the date of beginning work, it was found that the scour, in certain localities, was not proceeding with the rapidity which was desirable, and it was decided to contract the channel between the piers at those places by wing-dams. Such a contraction was thought to be specially necessary near the sea ends, on account of the leakage there through and over the jetties, which was greater as the end was approached—amounting, in the whole, to 35 or 40% of the water passing East Point. Eight wing-dams were built, arranged in pairs, from station 90 to 118. They narrowed the width from inside to outside of the jetties from about 950 to 700 ft. These spurs were hastily and flimsily built, consisting merely of a vertical mattress resting against a row of piles joined by a waling-piece. They did not stop the current completely, but only checked it. They were intended to be temporary structures and to meet an immediate want.

Afterwards the dams or dikes in question were raised to the surface of the water by mattresses laid horizontally. Many new spurs were built, in pairs as before, the space between the ends being reduced generally to about 650 ft., in places to 600 ft. or less. In July, 1877, 29 dams in all had been built. The wide space above the Kipp dam, which connected the West Jetty with the land, was also contracted by dikes, so that the distance from the East Jetty was reduced from 1,400-1,600 ft. to 570. In 1898, 50 dams had been built, of which 36 were then maintained. There were 13 more in the pass itself. Attention is called to these details, because the construction of these numerous contraction-works had an important effect upon the future of the pass. All these works were of a heavier and more substantial type than the earlier spurs, consisting mostly of tiers of mattress laid horizontally.

There was an extensive shoal across the head of South Pass, with a minimum channel depth of about 15.5 ft. at average flood tide, or something more than 14 ft. at average low water. To scour away this bar it was found necessary to construct extensive systems of training dikes and spurs at the Head of the Passes, and within the entrance to South Pass. These works were intended to divert a portion of the flow through Pass a l'Outre, and thus secure a greater head of water across the shoal. Sills were also laid across the heads of Pass a l'Outre and Southwest Pass. These structures were originally not intended to diminish the discharge through the passes named, but merely to keep them from enlarging pending the contraction of South Pass and the consequent diminution of its flow, which it was thought would be merely temporary. Subsequently, however (in 1878-9), the sill across Southwest Pass was raised, and became a submerged dam, nearly 8 ft. in height. An outlet on the right bank of South Pass, Grand Bayou, was closed entirely, by a brush dam. This outlet is about half way down the pass.

The Work of Improvement Since 1880.

Since 1880 the principal events in the history of the improvement of South Pass have been: The damage to the concrete capping and parapet of the East Jetty caused by storms, especially those of 1882 and 1886; the construction of the "inner jetties" in 1882 and subsequently; the rebuilding of the concrete walls in 1899; the progressive shallowing of the pass; the continued and enormous accumulation of silt behind the West Jetty; the scour on the sea side of the East Jetty; the annual subsidence of the works; the advance of the bar into the Gulf.

Damages to the Concrete Capping.

As early as Feb. 4, 1881, serious damage was done to the parapet of the East Jetty by a storm whose maximum velocity was 35 miles an hour; 1,215 ft. were more or less injured, and 97 ft. of concrete wall were destroyed. On Sept. 9, 1882, a wind from the north-northeast blew for 39 hours with an average velocity of 52 miles an hour. For 12 hours the average velocity was 67 miles; for one hour it was 92 miles; for half an hour 98 miles, and for a quarter of an hour 102 miles. The maximum was 108 miles an hour for five minutes. The tide was two feet higher than average flood.

The damage done to the jetties was confined to the east pier. Of this wall, more than one-half was protected by sedimentary deposits, and was, in fact, buried beneath them. A length of 5,432 ft, was exposed to the storm. This portion of the work consisted of concrete blocks resting upon a mattress foundation, and capped by a concrete parapet. Of this length, 2,430 ft. were badly broken up; many of the blocks with their capping were overturned on their sides, and one was turned upside down, while others were twisted out of line.*

On Oct. 11, 1886, a storm occurred which was not less violent than that of 1882, though it was of shorter duration. During the height of the hurricane (for such it was) the wind blew from the east-northeast, subsequently shifting to the east-southeast and southeast. The maximum velocity of the wind is not known, as the anemometer broke, but it is thought that it was fully as great as in 1882. The highest land in the vicinity of Port Eads (which is mostly made land) was overflowed, and even the houses were flooded. The damage consisted in the dislodging of 689 ft. of parapet near the sea end of the East Jetty. The condition in 1887 is thus described by Mr. Donovan:

> For 1,160 ft. the foundation blocks are in place, without the parapet, which was built upon them; for 2,512 ft. the parapet and foundation blocks are moved from their original position and badly broken up, and for 197 ft. the foundation and parapet have disappeared entirely.
>
> Most of the masonry on this jetty is above the surface of the water at high tide, and, even in its badly demolished condition, serves to break the force of the sea, which, after traversing the shoal area between it and the inner jetty, has but little force to expend on the latter, and thus the channel is secure against deterioration.†

The concrete work was rebuilt in 1889. In the meantime, interior lines of jetties had been built, which modified the situation materially.

Construction of the Inner Jetties.

The inner East Jetty was begun in the latter part of 1882 and was finished in 1884. The inner West Jetty was begun in 1886 and was finished in 1887. These works were of much lighter and cheaper character than the original jetties, consisting of piles and willow brush, the latter weighted with stone. The inner East Jetty was originally composed of two parallel rows of piles, driven 6 ft. apart each way; the space between the rows being filled with willows ballasted with stone. In localities where scouring took place under the jetties, the width of the dikes was increased, the number of rows of piles being then as many as four. The inner West Jetty was constructed very much after the same pattern. The

*"The History of the Jetties." New York; 1881.
†Corthell, pp. 202, 203.

†Donovan, in Report of Chief of Engineers for 1887, Part I., p. 1035, Part II., p. 1349.

piles were 8 ft. apart each way. The number of rows varied from one to five. When there was but one row of piles, the willows were placed so as to make the top of the jetty about 15 ft. wide. The piles near the sea ends were creosoted as a protection against the teredo. Throughout most of its length this jetty was built in only 2 ft. of water; so great had been the deposit caused by the wing-dams and other agencies.

The objects of these works were: (1) To prevent the escape of water at flood tide over the concrete blocks; (2) to keep the material which had accumulated between the wing-dams from being drawn into the channel by the swash of passing vessels; (3) to contract the waterway and increase the scouring power of the current.

The inner jetties were eventually brought up to a height of 4 ft. above the average flood tide, and the outer or sea slope was well covered with riprap.* The space between the East and West Inner Jetties was 675 ft. It was afterwards reduced to about 600 ft. by spurs or cribs.

Rebuilding the Concrete Walls.

In 1889 it was decided to rebuild the concrete wall of the East Jetty; and for two reasons: (1) The inner jetty was not intended to resist heavy seas, and the breakwater formed by the remains of the old concreting was not deemed sufficient; (2) the inner jetty was not closely consolidated, and there was considerable leakage through it. This would be prevented by building a close wall outside of it, and eventually a deposit would form between the two lines of jetty which would make the whole structure water-tight.

These expectations have in a great measure been realized; and the double lines of jetties answer their purpose very well. They also serve to prevent the carrying of large quantities of sand over the jetties into the channel by high seas, especially from the east. Storms from the west are rare, and when they do occur, the West Jetty is thoroughly protected from them by the immense deposits of silt which have accumulated behind it, almost to the very sea end.

The concrete blocks of the original jetties had been built with vertical sides, forming a perpendicular wall from 5.5 to 7.5 ft. high, resting upon a base from 4 to 12 ft. wide. To this peculiarity and to the high grade of the crown of the parapet (in 1886 said to be about 4 ft. above average flood tide) is attributed the extraordinary damage done by the hurricanes of 1882 and 1886. In the construction of the new wall this error was avoided, and the sea slope was given a batter of 1 on 1. The grade is 3 ft. above average flood tide. The work is locally known as the Wisner Wall, from the name of the engineer under whose direction it was built. No damage has been suffered since the date of rebuilding, except the annual subsidence.

Progressive Shallowing of the Pass.

In June, 1875, South Pass was, in Mr. Corthell's words, "a beautiful, natural ship canal." From the shoal at the head of the passes to the bar at the mouth, there was only at one place a depth less than 31 ft; and that was for a length of about 100 ft. Here (just above Grand Bayou) there was only 28 ft. In places, the depth was as great as 50 ft. After the obstacles above named should be removed, there was no apprehension of any trouble in the pass itself. Now, the maximum depth is about 36 ft. and the minimum depth 26 ft.; temporarily, sometimes less.

It is stated by Major Howell that South Pass, in 1875, carried off 15% of the total discharge of the river. This estimate was probably based upon only one or a few observations, for it does not agree either with earlier or later estimates. According to Capt. Talcott's survey of 1838, the percentage was about 8, and its cross-section, at its head, was 24,300 sq. ft. This accords very well with Mr. Marindin's survey of 1875. In 1878 Captain Brown found that the cross-section had decreased about 50%. In 1880 it had diminished by about 16%, namely, from about 24,000 above Grand Bayou to some 20,000.† The channel between the jetties had an area a little greater than this, but the effective section was reduced by spurs. In 1889 the section above Grand Bayou was still farther reduced to about 19,000 sq. ft. In 1891, a crevasse occurred in Pass a l'Outre, increasing considerably the proportion of water carried off through that branch and diminishing the discharge of the other two passes. During a year's observation, in 1878, the proportions were 46, 43 and 11. In 1898, the respective percentages were about 50, 41 and 9. In 1897, the cross-section of the part of South Pass above Grand Bayou was about 17,500 sq. ft.; a diminution since 1875 of about 27%. Between the jetties it was almost exactly the same.

This tendency toward deterioration of the pass did not escape detection. Up to 1878 there had been observed a gradual contraction of the channel above Grand Bayou, which was, however, attributed to the influence of the works at the head of the pass. In 1880, it was remarked that there had been an average fill throughout the pass, since 1875, along the channel line, of 2.5 ft. In 1886, the total fill above Grand Bayou varied from 4 to 12 ft, and below Grand Bayou from 3 to 7 ft. The shoaling was generally in the deeper portions of the pass, and did not injure navigation. In 1888, the fill above Grand Bayou, since 1875, was from 1 to 18 ft.—below Grand Bayou, from 3 to 9 ft. In 1897, the total fill above Grand Bayou varied from 5 to 30 ft, and below Grand Bayou from 2 to 14 ft. If the shoaling had been confined, as it was at first, to the deep sections, it would have done but little harm. It was thought by those in charge that it indicated a marked tendency toward uniformity of depth, by the deeper localities being filled up, while the shallower places remained unchanged or deepened. Lately, however, the fill has also extended itself to the shallows; in fact, it is general throughout the pass.

In order to hasten and facilitate the acquisition of the required dimensions of channel, Mr. Eads had constructed in 1877 a powerful dredge boat called the "G. W. R. Bayley," in honor of the distinguished engineer who was then his principal assistant. This boat is a suction-dredge of the kind sometimes called "self-loading;" that is, she carries hoppers or tanks into which the dredged material is pumped, to be discharged afterwards between the wing-dams or in deep water at sea. When strong currents prevailed, she discharged the material directly overboard. This boat was used only occasionally, during the construction of the jetties, and from February, 1883, to August, 1888, a period of 5½ years, she was not used at all. When she was put into employment, it was generally in the jettied channel. She was rarely needed at the Head of the Passes, in the pass itself or in the Gulf. She was not used in the pass until 1893. From 1888 to 1897, inclusive, 80% of the dredging was done between the jetties, 13.3% in the South Pass proper, 6.4% in the Gulf and 0.3% at the head of the passes. From 1893 to 1897, inclusive, the respective proportions were 74.4, 20, 4.8 and 0.8. In 1897, out of 108 days of 10 hours each of dredging, 68 were spent between the jetties, 33 in the pass and 7 in the Gulf. In 1895 the dredge was in use for 141 days. The channel was below the required dimensions 31 days. In 1896, dredging was done for 130 days and the channel was deficient for 139 days.

Sand Waves in the Pass.

According to the engineers engaged in the work, the immediate cause of this trouble is the passage of sand-waves. Except for the disturbance caused by these moving masses of material along the bottom, the channel is nearly constant in position. The waves, Mr. Donovan thinks, were originally made by deposit of matter in suspension. After the material is dropped, it is probably rolled along the bottom; the forces that were insufficient to hold it suspended being amply competent to push it. "This phenomenon," says Mr. Donovan, "almost invariably occurs in some part of the channel when the river is approaching its highest stage and when it begins to fall. At such times the channel is constantly changing, volume after volume of sand following each other, and while it is reasonable to presume that dredging will aid in disintegrating them, yet, following as they do in rapid succession, particularly when the tide begins to ebb, the effect of dredging is often obliterated during the night, and at times when the dredge is working it has been observed that the shoaling was increasing. The amount that these sand-waves reduce the depth of the channel is rarely 3 ft, and generally varies from 1½ to 2 ft."*

In 1896, from August to December, 122 days, the failure to maintain the required depth occurred at different localities in the channel between the jetties—very little elsewhere. To quote again from Mr. Donovan:

> A deep place to-day would be found shoal on the following day, and although a vigorous attempt was made to restore the channel by dredging, the progress made was extremely slight. The strong salt-water reverse current which exists during low river seemed to keep the bottom alive; a moving mass of very soft material was always present near the bottom, and whatever improvement might be made when the tide was ebbing would be obliterated during the rising tide.

This soft material, which is brought in from the sea by the flood-tide, is not as dangerous to vessels running aground upon it as the ordinary harder sand or silt composing the bottom. It is so soft indeed that ships often force their way through it. "On Nov. 23, 1896, dredging was discontinued, and on Dec. 16 the channel was found to have become restored solely from the effect of a 3-ft. rise of the river."

Mr. Donovan states that the most unfavorable stage of the river is a rapid fall after a considerable rise. This condition is analogous to that which prevails in the reaches of the Mississippi between Cairo and Red River, or indeed in the body of any sedimentary stream. The best effects are experienced after a long medium stage, though a gradual rise and an equally gradual fall produce good results. Contrary, however, to what prevails in the river, a prolonged low stage does not seem to bring about a good navigable channel. This fact is attributed to the proximity of tide-water, whereby a low stage in the river is accompanied during flood and slack-water by very low velocities, while even at ebb the current is but small. In the upper reaches of the Lower Mississippi, on the other hand, the low-water velocity is often 3 ft. per second, and seldom less than 2.

One of the most troublesome junctures is when several short rises follow in rapid succession at low stages, bringing down heavy volumes of sediment from some of the tributaries, without producing any proportional augmentation of depth or slope, or consequently of velocity and transporting power. It was found by Dr. Branner in the Arkansas River in October, 1891, that a rise from the silt-carrying Canadian River, coming upon a low stage of the Arkansas (namely, 4 ft. on the gage at Little Rock) when the latter stream was comparatively clear, brought such an enormous volume of sediment that the proportion of solid matter in suspension to water in the Arkansas at Little Rock, 250 miles below the mouth of the Canadian, was 1-82 by weight; and this sediment was carried a great distance. The rise in the Arkansas was only 3 ft.

The trouble in 1896 and subsequently was caused apparently by the passage of sand-waves of rather coarse material, probably coming from the Missouri, possibly from the Platte, as there were heavy rises from that region some four weeks before. After the sediment had been dredged up by the "Bayley" and dropped overboard, as is the usual manner of operating that boat when there is a current, it fell rapidly to the bottom again. The dredging done in 1898 was considered to be a useless expenditure of labor and fuel, and eventually it was discontinued. An experiment made in that year upon the method of depositing the dredged material near the banks of the pass showed that after two weeks or so of work there was almost no gain of depth or of navigable width.

There are pools and shoals, bends and crossings in this narrow, regularized channel, just as there are in the open river, but the shoals are under water instead of being exposed to view. The shallow places are generally or always on the crossings from bend to bend or reversion-points of the curves. This circumstance might be due, in part at least, to the fact, first noted, it is

*Major Heuer, in Report of Chief of Engineers for 1886—Part II., pp. 1226-7.
†Corthell, "History of the Jetties."

*Report of Chief of Engineers for 1897—Part II., p. 1740.

thought, by Dupuit, that at such places the effective cross-section, normal to the direction of the current, is greater than elsewhere, owing to the obliquity of the channel to the axis of the stream. In a natural river the actual breadth is always greater at a crossing than in a bend; but in a normalized stream the breadth is usually made uniform by restraining works.

The Waal is a strictly regularized river, and it might be thought, and indeed it was thought, that the uniformity of breadth should be preserved in the crossings, as well as in the bends. Experience showed, however, that a uniform navigable depth could not thus be preserved; and it was found necessary to reduce the standard width of 360 meters to 310 in the straight reaches and the

Fig. 3.—Sketch Showing Formation of Middle Ground Along the Axis of a Stream.

crossings. In the case of straight reaches the principal difficulty encountered is the formation of what the river-men call a "middle ground;" that is, a shoal in the axis of the stream, with deep water next to either bank, as shown by Fig. 3.

The movement of sand-waves is well shown by Mr. Donovan in several of his reports; for instance, in that which is published in the Report of the Chief of Engineers for 1897, p. 1740, Plate III. They are worthy of a careful study. Without going into details, it is sufficient for the present purpose to observe that under existing circumstances the channel is liable to interruption at any time from this cause should unfavorable stages of the river supervene, and that relief, when it comes (sometimes after an interval of months) must proceed from a change in the condition of the river.

Mr. Donovan attributes this evil to a combination of several causes; the escape of water over the banks of the river between the lower end of the levee system (about the neighborhood of the Forts) and the head of the passes; the increased escape of water through Cubitt's Gap, Baptiste Collet's canal and Pass a l'Outre; but especially to the fortuitous and apparently incalculable and unpreventable effects of stage of the river. If the last be the predominant, as it appears to be the immediate cause, then the case seems to be difficult of remedy by works of regulation; that is, there appears to be no way to insure by such means the preservation of an uninterrupted channel against the influence of unfavorable stages, and the interruption may be of prolonged and unknown duration. Dredging would seem to be the only remedy that presents itself. This has not been seriously tried.

Cause of the Deterioration of the South Pass Channel.

It is clear, however, that some influence is at work now which did not operate formerly; for it is in evidence that up to 1888 there was little or no difficulty with the channel. Up to 1893 there was very little trouble in South Pass, the obstruction being mainly in the channel between the jetties, where about four times as much dredging was done as in all the other stretches from the River to deep water in the Gulf put together.* Of the causes enumerated above, the escape of water over the banks has always been in operation, and to a greater extent formerly than at the present day. Probably the volume of water poured out through the passes and outlets together is not less than it was in former times; it is rather more. No more sediment is brought down the river, in proportion to the quantity of water, than before the construction of the jetties. The flow through Cubitt's Gap and The Jump is no greater than it was in 1875; it is probably less. The discharge of Pass a l'Outre has apparently increased since 1878, and there seems to be little doubt that the discharge of South Pass has diminished. These matters are difficult of accurate ascertainment; but according to the best evidence obtainable in 1878 the discharges of the three passes were about as 46, 43 and 11; now they are as 50, 41 and 9.

That this decrease in the flow of South Pass should have as an effect a deterioration of the pass is conformable to reason and experience; and it is proven that the silting-up has progressed more rapidly since the occurrence of the crevasse in Pass a l'Outre in 1891. The deterioration, however, had begun, as we have seen, many years before 1891. In fact, the greater part of the contraction of section occurred during the building of the jetties, in which period the area of the pass diminished 16% out of a total of 27%.

It is obvious that before the deterioration reached serious proportions, the changing conditions of river-stage, etc., produced travel of sand-waves in very much the same manner that they do at present. These movements, however, were the occasion of very little inconvenience, for in most places the depths were so great that the disturbance of the bottom was not noticeable. For instance, in 1883, in Grand Bayou reach there were only two or three isolated lumps that were less than 30 ft. below the surface of the water, where there is now a continuous shallow stretch a mile and a half in length, so little deeper than the prescribed minimum that the passage of a series of sand-waves is likely to cause serious inconvenience to large vessels and an interruption for the time of the channel required by law.

While this condition has been aggravated, no doubt, by the unfavorable circumstances which have existed, it is not entirely caused by them. Had the channel through the pass remained as it was in 1883, the passage of sand-waves could never have produced any considerable disturbance of navigable conditions. It is the silting-up of the pass which is the primary cause of the trouble. Sand-waves are of universal occurrence in the Mississippi, as in other sedimentary rivers, along its whole course at all stages, except high ones, when they are in great measure leveled and obliterated by the velocity of the current. They are of vastly greater dimensions than those which are met with in the passes. It is only in shoal water that they are the cause of any annoyance.

The fill referred to has been enormous—something like 13,000,000 cu. yds. It is important to ascertain the cause of it; for the same influences which have produced such an effect here will be at work to accomplish a similar result at Southwest Pass, should the work now projected be undertaken there and at other localities where like conditions prevail, unless due precaution be taken.

One is naturally led to the supposition that over-contraction may be the principal cause of this trouble. The banks of the passes are very low—are overflowed at high stages of the river. Now contraction is valuable only in increasing the head, and consequently the velocity and the scouring power. But there is a limit to the head which can be obtained in the passes. The limit depends on the height of the banks. It is true that even after the water has begun to flow over the banks an additional head can be gained, for it requires head to give the lateral current necessary for the escape of the superfluous water; but this head too has a limit, and it is soon reached. After it has been reached additional contraction can do no good. It is merely obstruction. The effect, then, of over-contraction would be to check the flow of water through the passes, and to encourage a greater flow through the other passes and outlets. As the sections above the contracted part have a greater area than the latter, they will silt up. In 1880 Mr. Corthell wrote:

> The average area of the section of the passes above Grand Bayou was in 1875, about 24,000 sq. ft. The enlargement of the section of the pass below Grand Bayou has been progressive since the construction of the dam across that outlet. The area of the section in the jetty channel will, no doubt, eventually be fully equal to that of the pass above Grand Bayou. Sir Charles Hartley and Mr. Eads have from the first contended that the channel through the jetties will be even larger than that of the pass itself.*

But suppose the jettied channel refuses to scour. There are numerous instances in which this obstinate disposition on the part of a river has been encountered. In the case of the New Waterway from Rotterdam to the Sea from 1874 to 1877 the cut through the Hook of Holland, which was expected to be completed by the unaided action of the current, declined to scour any more, and finally it was found necessary to resort to dredging; so that the cost of the finished channel was nearly six times the original estimate. Then, in the case of the South Pass, instead of the jettied channel cutting out to the dimensions of the pass, the pass would fill up and contract itself to the cross-section of the jettied channel.

This is what actually happened. It was necessary, by the terms of the concession to Mr. Eads, that he should obtain a channel of 20 ft. in depth by September, 1877, and of 2 ft. additional depth in each succeeding year. For financial reasons, it was imperative to hasten the process of scour with all possible promptitude. Dredging was not at first contemplated, and indeed it was a matter of doubt whether it was allowable. When at last it was resorted to, it was only tolerated as an auxiliary means of obtaining the required channel, reliance being placed on the contraction-works to do almost all the labor of excavation and maintenance. It was estimated that only about 1% of the work was done by the dredge-boat.

Contraction, therefore, was relied upon to do everything; and it was pushed forward with precipitancy. Wing dams were begun as early as May, 1876, and their construction has been continued ever since. They were intended, at first, to be temporary, but they were strengthened and raised and, finally, the reduction of section was made permanent by the building of the inner jetties. After the completion of these works, the section between the jetties, which had a minimum in 1880 of 20,000 sq. ft., had, in 1889, a minumum area of 16,000 sq. ft., and an average area of 16,500. In 1897, the average area between the jetties was 17,400 sq. ft., not counting the additional contraction introduced by the spurs inside of the inner jetties, which still further reduce the effective section.

It may be a matter of serious question whether the great reduction of area between the jetties from 1880 to 1889 did not contribute, in some measure, to the occurrence of the crevasse in Pass a l'Outre. Certainly it must have caused an increased flow through that branch, and an increased head at its upper end. Since the enlargement of the break to formidable dimensions, it has in its turn reacted upon the other passes, robbing them of a portion of their flow and no doubt contracting somewhat their dimensions. It is to be observed that the sections below Grand Bayou have never cut out to the area of the sections above that point. As well as we can tell, from the crudeness of the data, the relation between the two parts of the pass were nearly the same in 1897 as in 1880.

The silting up of South Pass has, to all appearance, nearly reached its limit, unless the crevasse in Pass a l'Outre should keep on enlarging, or unless some other external disturbing cause should occur. The pass has very nearly contracted itself to the dimensions of the channel between the jetties, and there seems to be no special reason why the latter should be reduced to any smaller area. Unfortunately, both pass and jettied channel have been so diminished in depth that the passage of sand waves may cause trouble at any time. With modern appliances for dredging these obstructions might be removed without inordinate expense, or, still better, the shallow portions of the pass might be deepened so much that the passage of the sand waves should no longer be a serious hindrance to navigation.

There is a limit, of course, to the deepening and enlargement of the pass. With a natural width of only 600 or 700 ft. it will never be possible that it should furnish a channel of adequate width and depth to the long and constantly growing vessels of the present and the future. The channel projected for Southwest Pass is intended to have a depth of at least 35 ft. at low water and a width at the bottom of about 1,000 ft.

Accumulation of Silt Behind West Jetty.

When the improvement of South Pass was still in its rudimentary stages, it was observed that de-

*See Mr. Donovan's testimony before the Senate Committee on Commerce in 1898, and his letter to Senator Nelson.

*"History of the Jetties," pp. 229-30.

posits were taking place on the sea side of both jetties. In December, 1877, there had been a shoaling behind the East Jetty for a distance of 1,000 or 2,000 ft. from the mattress-wall. Behind the West Jetty "shoaling had been progressive and constant"; varying from 12.3 ft. at the upper end of the jetty to 1 ft. near the lower end. The deposits consisted mostly of white sand.* In 1879, the shoaling was still more decided, though far greater behind the West Jetty. It extended, in each case, from the land's end out into the Gulf. On the western side, the process has continued, and is still going on. In 1898, the whole of the West Jetty was buried beneath the land which had been formed by accretion under its lee, except a few hundred feet at the sea end. This "made land" was covered by a thick growth of reeds and swamp grass. At the sea end it was much higher than the water, the sand having been heaped up by the action of winds and waves after the fashion of dunes, on a small scale.

It is said by those engaged in work at South Pass that Mr. Eads might have saved hundreds of thousands of dollars if he had had more accurate information about prevailing winds and currents. For instance, he might have spared most or all of the concreting of the West Jetty.

Scour on Sea Side of the East Jetty.

The fill outside of the East Jetty was progressive or stationary from 1879 to 1882, when the land which had formed by accretion for more than half of its course began to be scoured away. By 1887, about 900 ft. of it, measured along the line of the outer jetty, had disappeared. In 1893, about 1,100 ft. more had been lost. In 1898, the line of the land outside of the old East Jetty had receded altogether 3,300 ft. since 1882, leaving about 3,000 ft. of the outer or original wall still covered by deposit. The cause of this remarkable phenomenon is not well understood. It is possible that it may be due to the impounding of the waters of Garden Island Bay by the east winds which usually prevail at the passes, and a consequent superelevation there, giving head enough to generate a destructive velocity along its western shore. So formidable is the movement of recession of the shore line that it is apprehended that Port Eads itself may be in danger at no remote date. No measures have yet proved effective in preventing the recession.

It may be remembered that a very similar occurrence took place at the Sulina Pass of the Danube; there, as here, behind the east jetty. At the mouths of the Danube, as at the mouths of the Mississippi, the prevailing winds and currents are from east to west. Accretion had taken place there too behind both jetties, when, after the expiration of about ten years, a scouring movement supervened behind the east jetty, which proceeded to such an extent that the jetty had to be extended landward 1,000 ft. or so, if recollection serves. Sir Charles Hartley's paper is not now at hand.

Subsidence of the Jetties.

The bottom on which the jetties were built is a silt or mud, composed of clay and finely comminuted sand. It is therefore soft and compressible, at least for some distance below the surface. It is said that it usually gets harder after about 2 ft. in depth.† It is still so soft, however, that massive structures built upon it would sink into it to a great and, what is worse, an unknown extent. It was for this reason, among others, that Mr. Eads built his jetties of such light materials, being guided thereto, in part, by the experience of Mr. Caland at the New Rotterdam Waterway. It was found, however, that very light structures were subject to serious objections. They had not stability enough to resist the attacks of storms; they were subject to decay; and they were too permeable, allowing the escape of very large quantities of water, the retention of which was essential to the success of the work. It was therefore found necessary to load them rather heavily with stone and to give them a capping and parapet of concrete.

It is difficult to ascertain with precision the amount of settling of the two jetties. If the elevation of the crown merely were to be taken at different times, for purposes of comparison, the difference in a term of years would be composed of at least three elements; the settlement proper of the bottom of the jetties in the mud; the compression of the willow mattresses; and the secular movement of subsidence which is going on, as we have seen, all along the Gulf in the vicinity of the mouths of the river, and most of all in the immediate neighborhood of the passes themselves. To these may be added occasional undermining by waves and currents. In 1886, the subsidence of the concrete wall of the two jetties was as follows, excluding portions damaged by the storm of 1882:

East jetty, for 5 years, average tofal subsidence...1.34 ft.
West jetty, for 6 years, average total subsidence...1.53 "

In 1889, the concrete wall of the East Jetty was rebuilt, as has been narrated. In 1898, the total settlement of the new wall had been, on an average, 1.4 ft. Of this, probably 0.4 or so was due to secular subsidence. The gross loss of height resulting from all causes except undermining is thought by those in charge of the work to vary from about 3 or 4 ft. at the land's end to 7 or 8 ft. at the sea end—decreasing rapidly from the latter point landward.

Advance of the Bar Into the Gulf.

The advance of the bar into the Gulf, as shown by Fig. 4, has been at the mean rate, for all contours, of 1,560 ft. in the twenty years from 1877

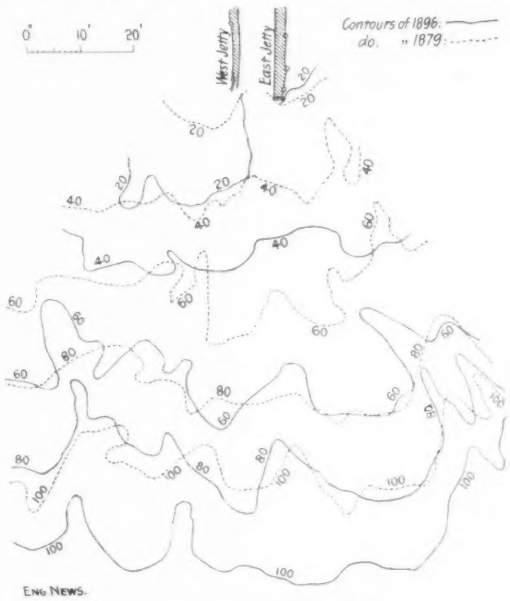


Fig. 4.—Sketch Map Showing the Advance Into the Gulf of the South Pass Bar.

to 1896 inclusive, or at the rate of 78 ft. for each year.* The smaller depths have advanced least. The 20-ft. contour has advanced into the Gulf 641 ft.; the 30-ft. contour 1,000 ft.; the 40-ft. contour 1,149 ft.; the 50-ft. contour 1,228 ft.; while from the 60-ft. to the 100-ft. contour the mean advance has been 1,862 ft. The average annual advance of the curves from 20 to 50 ft. inclusive has been 53 ft., while of those from 60 to 100 ft. it has been 98 ft. The annual advance of the crest of the bar (which may be assumed to be about the same as the 20-ft. contour) before the construction of the jetties, was about 1,069 ft. Now it is about 32 ft.

Winding through the bar, and assuming very much the same form and the same location that it had in 1879, is a channel more than 30 ft. in depth, with width of 100 ft. or more, at the narrowest place, between the 30-ft. contours. The line of deepest water curves pretty sharply toward the southeast, with a mean radius of curvature of about 11,000 ft. as far as the 100-ft. contour, beyond which it has not, apparently, been traced. This direction is in conformity with a general principle which has been thus enunciated by Mr. Corthell.

It is an observed fact that delta-forming rivers, when they enter the sea, have a tendency to direct their currents against the littoral currents of the sea, for the reason that the suspended sediment which they discharge is carried by the sea to the leeward bank of the river, and the accretions which are made upon this bank from the river-discharge cause it to grow more rapidly than the other, and finally to curve the fluvial current around against the littoral current." The force of this observation will be made quite evident by an inspection of the comparative chart shown herewith.*

The deep-water channel thus existing is evidently maintained by the large volume of moving water issuing, in a concentrated stream, from the jetties, which does not immediately disperse on reaching the waters of the Gulf, but maintains its integrity, to a considerable extent, for a long distance. It is said that it is recognizable, as a "river in the ocean," for 20 or 30 miles from its mouth.

*Eighth Report on the Jetties, p. 22.
†Ockerson's "Survey of Southwest Pass," p. 33.

*Donovan, in Report of Chief of Engineers for 1897—Part II., pp., 1744-5.

*Corthell's "History of the Jetties," pp. 73, 74.

TRIAL OF AN ALLIS TRIPLE-EXPANSION PUMPING ENGINE; CHESTNUT HILL STATION, BOSTON WATER-WORKS.

The large Allis pumping engine in the Chestnut Hill high-service pumping station of the Boston Water-Works was given a contract duty trial on May 1 and 2, 1900, and its results are of exceptional interest by reason of the very high duty attained. The trial was conducted by the engineering department of the Metropolitan Water Board, represented by Dexter Brackett, M. Am. Soc. C. E., Engineer, Distribution Department, and Will J. Sando, M. Am. Soc. M. E., Superintendent, Pumping Stations. The E. P. Allis Company was represented by Arthur J. West, M. E.

The engine, which is officially known as No. 4, was designed and built by the E. P. Allis Co., of Milwaukee, Wis., in 1897-98. The engine began running in December of the latter year. We have been furnished with an official description of the plant and report of the test, which we print as follows:

Description of Plant.

The engine is of the vertical triple expansion self-contained type, with three single-acting outside packed plungers, having at contract speed (about 17½ revolutions per minute) a capacity of 30,000,000 U. S. gallons in 24 hours. The pump plungers are placed directly under the steam cylinders and rigidly connected with the steam pistons.

The steam inlet and exhaust valves for the h. p. cylinder and the inlet valves for the i. p. cylinder are of the Corliss type; the exhaust valves for the i. p. cylinder and the inlet and exhaust valves for the l. p. cylinder are of the poppet type. All valves receive their motion from a lay shaft which is driven from the crank shaft by means of two connecting rods. The cut-off on the h. p. cylinder is controlled by an automatic centrifugal governor, and is also adjustable by hand. On the i. p. cylinder the cut-off is adjustable by hand and on the l. p. cylinder the cut-off is fixed.

The cylinders are jacketed on the barrels. All valves are placed in the cylinder heads and jacketed only by the working steam. There are receivers, fitted with copper reheating coils, between the h. p. and i. p. cylinders and the i. p. and l. p. cylinders. The volumes are respectively 4½ and 2¾ times the volumes of the preceding cylinders.

The system of steam distribution through the jackets and receiver coils is as follows: The h. p. jacket is supplied with steam from the main steam pipe at the same pressure as the steam at the throttle valve, the first receiver coil is supplied from the h. p. jacket outlet, and the i. p. jacket is supplied at a reduced pressure from the first receiver coil outlet. There is also discharged into the i. p. jacket the water drained from the first receiver coil inlet, there being a ¼-in. pipe and globe valve provided for this purpose. From the i. p. jacket the mixture of steam and water enters the second receiver coil, and from here is trapped and discharged into the bottom of the second receiver, and is then trapped to waste. The l. p. jacket is supplied with steam, at a reduced pressure, from the working side of the first receiver. The connection is taken out at the bottom of the receiver to prevent the water of condensation from entering the i. p. cylinder. To insure circulation in the l. p. jacket there is a ¼-in. free pipe connection from the top of the jacket to the working side of the second receiver. The drain from the l. p. jacket is trapped to waste. The drain from the separator is discharged into the top of the first receiver. To keep steam on the l. p. jacket when the engine is not running, a by-pass pipe is provided on the trap which drains the first receiver coil, so that instead of discharging into the second receiver the mixture is discharged into the l. p. jacket.

The surface condenser contains 2,000 sq. ft. of cooling surface. The circulating water is taken from and returned to the suction pipe. Directly on top of the condenser there is an exhaust heater which contains 300 sq.

ft. of heating surface. The boiler feed pump is attached to and driven by the main engine. The feed water is taken from the out-board circulating pipe of the condenser, and on its way to the pump suction passes through the heater. The air pump and the air compressor for charging the discharge air chambers are attached to and driven by the main engine.

Each pump is composed of five principal castings. They are locked at right angles to the longitudinal center line of the engine. On one side there is a suction valve chamber and on top of this a suction air chamber. On the opposite side there is a discharge valve chamber and on top of this a discharge air chamber. The suction and discharge valve chambers are connected by the plunger chamber. The suction, discharge and plunger chambers rest on and are bolted to a masonry foundation, and the engine bed-plate rests on and is bolted to the top of the suction and discharge air chambers, thus forming a self-contained structure.

The three pumps are connected longitudinally by the suction pipe on one side and the discharge pipe on the other. The pump valves are ⅝-in. thick and made of the best grade of medium rubber. The valve seats are made of composition and are mounted in groups of 35, on cages which can be easily removed from the chambers. The free waterway through each set of suction and discharge valve seats is 121% of the area of the plunger.

Steam was furnished by a double furnace Belpaire boiler, designed by E. D. Leavitt, M. E., of Cambridge, and built by the Lake Erie Boiler Works of Buffalo, N. Y. Each furnace is equipped with a mechanical stoker, made by the American Stoker Co., of New York. Forced draft for the stokers is supplied by a B. F. Sturtevant, Boston, Mass., blower outfit. The escaping gases pass from the boiler around the tubes of a Green economizer, built and erected by the Fuel Economizer Co., of Matteawan, N. Y. The feed water is pumped through the tubes of the economizer on its way to the boiler.

Method of Conducting the Trial.

The contract provided that the engine should perform a duty of 150,000,000 ft. lbs. for each 1,000 lbs. of commercially dry steam used by the engine and any auxiliary pumps supplied by the contractor, steam containing less than 1½% of entrained water, as determined by calorimeter measurement, to be considered as commercially dry steam; the work performed by the engine to be based upon plunger displacement.

As the contract requirement for duty was based upon the quantity of steam used by the engine, great care was taken to accurately determine the amount used. All connections between the boiler which supplied steam to the engine and the other boilers in the station were either broken or closed with blank flanges. All condensed steam from the low-pressure cylinder was discharged by the air pump into a wrought iron tank from which it was drawn into a second or weighing tank, and from there it was discharged into a third tank from which the supply for the boiler was taken. Wrought iron tanks resting on platform scales received the condensed steam from the separator, the jackets of the high and intermediate steam cylinders and receiver coils and the jacket of the low-pressure cylinder. The condensed steam before entering the weighing tanks was passed through coils submerged in cold water in order to prevent loss from evaporation.

The water from all of these tanks, after being weighed, was discharged into the large suction tank and was from there forced into the boiler by the feed pump attached to the main engine. The supply to the boiler was regulated by means of the by-pass through which the discharge from the feed pump could be returned to the suction tank.

During the test all steam used by the stoker cylinders and blowing engine, and the economizer engine was supplied by another boiler, so that if there had been no leakage from the boiler, economizer and piping, the quantity fed into the boiler would have agreed with the quantity received from the engine and separator. In order to determine the amount of leakage from the boiler, economizer and piping, a test was made on April 28 and 29. For 24 hours the steam pressure in the boiler was maintained at 190 lbs., the throttle valve at the engine was closed, and hourly observations were made of the condensed steam from the jackets and separator and of the elevation of the water in the boiler. Sufficient water was pumped into the boiler to bring the water level to the same elevation at the end of the 24 hours as it was at the beginning, and it was found that the leakage from the boiler, economizer and piping was at the rate of 46.35 lbs. per hour.

(We omit here a description of the method of making the observations during the trial.—Ed.)

As the contract duty was based upon steam consumption and not upon the amount of coal used, it was not deemed advisable to attempt to begin the test with a new fire under the boiler, or to draw the fire at the close of the trial. Fires were cleaned about two hours before the test began, and once during the 24 hours, which is the regular practice in operating the station. It is thought that the recorded weight very closely represents the actual quantity of coal burned during the 24 hours.

The coal used during the trial was the Loyalhanna, Sonman Shaft, run-of-mine coal in regular use at the station. The coal was tested for its calorific power, and the thermal units given in the table represent the value of one pound as actually used.

General Data.

Principal Dimensions of Engine.

Diameter HP. cylinder (nominal)	30 ins.
" I. P. " "	56 "
" L. P. " "	87 "
Cylinder clearances:	
High pressure	1.35%
Intermediate pressure	.55%
Low pressure	.45%
Diameter of plungers (nominal)	42 ins.
Stroke of pistons and plungers (nominal)	66 "
Diameter suction and discharge pipes	48 "
Diameter fly-wheels (2)	20 ft.
Weight of each wheel	50,000 lbs.
Revolutions per minute for capacity	17.5
Speed per minute	192.5 ft.

Principal Dimensions of Boiler Plant.

Boiler, diameter	90 ins.
Boiler length (over all)	34 ft. 4 ins.
Number of tubes	201
Diameter of tubes	3 ins.
Length of tubes	16 ft.
Heating surface	2,849 sq. ft.
Grate area (2 furnaces)	63.875 sq. ft.
Ratio of heating to grate surface	44.6 to 1
Economizer heating surface outside of tubes	1,680 sq. ft.

American mechanical stokers used under boilers with forced draft.

Measured and Calculated Dimensions.

	Diam. steam cylinders.*	Area steam pistons.†
High pressure: Top	30.05	709.22
Bottom	30.05	675.62
Intermediate: Top	56.04	2,466.53
Bottom	56.04	2,432.93
Low pressure: Top	87.07	5,954.26
Bottom	87.07	5,920.66

*At temperature due to actual working conditions (calculated ins.).

†Area steam pistons under working conditions, sq. ins.

	High pressure.	Inter-mediate.	Low pressure.
Stroke, ft.*	5.500	5.4948	5.4974
Area of plungers, sq. in.	1,387.5067	1,387.1880	1,386.8064
Displacement.†	52.9073	52.9328	52.9433
No. steam piston rods.	2.	2.	2
Diam. st. piston rods, ins.	4.625	4.625	4.625

*Of pistons and plungers, engine running.

†Displacement of one plunger per rev. (water 62.4 lbs. per cu. ft.), cu ft.

Trial Data.

Duration of trial, ...24 hours, from 9.15 a. m., May 1.

Average Pressures.

Steam at boiler	187.37 lbs. per sq. in.
Steam at throttle	185.47 " " " "
1st receiver	30.85 " " " "
2d receiver	3.31 " " " "
Vacuum (28.16 in. mercury)	13.80 " " " "
Barometer (29.85 in. mercury)	14.63 " " " "
H. P. jacket	185.47 " " " "
I. P. "	73.40 " " " "
L. P. "	4.80 " " " "

Average Temperatures.

Steam at boiler	382.95° F.
Steam leaving L. P. cylinder	116.41° "
Water from 2d receiver	197.45° "
Water from L. P. jacket	205.07° "
Water discharged from air pump	76.19° "
Water in condenser tank	76.19° "
Water in 2d receiver tank	90.44° "
Water in L. P. jacket tank	83.88° "
Water in separator tank	60.94° "
Water in make-up tank	52.67° "
Water entering economizer	79.72° "
Water leaving economizer (fed to boiler)	154.98° "
Water cond'ser circulating inlet (water pumped)	52.67° "
Water condenser circulating outlet	78.79° "
Flue gases leaving boiler	485.40° "
Flue gases leaving economizer	221.90° "

Data for Head Pumped Against.

Average elevation of water in force main above Boston City Base	271.856 ft.
Average elevation of water in wet well above Boston City Base	131.506 "
Average net head pumped against	140.350 "

Revolutions.

Total revolutions during 24 hours	25,539.
Average revolutions per minute	17.7354

Useful Work Performed by Engine.

Water pumped per revolution plunger displacement	158.8732 cu. ft.
Water pumped per revolution (at 62.4 lbs. per cu. ft.)	9,913.7 lbs.
Total plunger displacement	30,351,926 U. S. gals.
Plunger leakage	38,015 U. S. gals.
Water pumped (no allowance for slip)	30,313,911 U. S. gals.
Net ft. lbs. useful work deducting plunger leakage	35,490,102,245 ft. lbs.

Steam Out of Boiler Not Used by Engine.

Water from separator	2,019.0 lbs.
Steam blown through calorimeter (weighed in tank)	649.0 "
Leakage from whole plant, exclusive of engine	1,112.5 "
Total steam out of boiler not used by engine	3,780.5 "
Total water fed to boiler	205,370.0 lbs.
Steam chargeable to engine	201,589.5 "

Steam Received from Engine.

From condenser	170,427.0 lbs.
From L. P. jacket	25,886.5 "
From 2d receiver	5,276.0 "
Total steam used by engine (same as above)	201,589.5 "
Average entrainment in steam entering engine, 1.37%	2,761.8 "
Total dry steam used by engine	198,827.7 "
Percentage of total steam used in jackets	15.45%

British Thermal Units.

Heat of vaporization steam 200.10 lbs. absolute	=	843.77 B. T. U.
Heat of liquid, 200.10, absolute	=	354.64 " " "
Heat of liquid discharged from condenser, Temp. 76.19° F.	=	44.30 " " "
Heat of liquid discharged from 2d receiver, Temp. 197.45° F.	=	166.15 " " "
Heat of liquid discharged from L. P. jacket, Temp. 205.07° F.	=	173.77 " " "
Heat of vaporization steam at boiler 202 lbs., absolute	=	843.20 " " "
Heat of liquid at boiler 202 lbs. absolute	=	355.40 " " "
Heat of liquid entering economizer, Temp. 79.72° F.	=	47.81 " " "
Heat of liquid entering boiler, Temp. 154.98° F.	=	123.28 " " "
Heat per lb. of moist steam used in cylinder, 843.77 × .9863 + 354.64 − 44.30	=	1,142.55 " " "
Heat per lb. moist steam used in H. P. and I. P. jackets and receiver coils, discharged from 2d receiver, 843.77 × .9863 + 354.64 − 166.15	=	1,020.70 " " "
Heat per lb. of moist steam discharged from low-pressure jacket 843.77 × .9863 + 354.64 − 173.77	=	1,013.08 " " "
Heat put into feed water by economizer, 123.28 − 47.81	=	75.47 " " "
Heat put into steam by boiler, 843.20 + 355.4 − 123.28	=	1,075.32 " " "
Heat to convert condenser water to steam	=	194,721,400 " " "
Heat to conver' L. P. jacket water to steam	=	26,225,100 " " "
Heat to convert 2d receiver water to steam	=	5,385,200 " " "
Total heat used by engine	=	226,331,700 " " "
Heat contained in one lb. of wet coal	=	14,023 " " "

Horse-Power Figures.

Average percentage of friction of engine (Av. of 18 sets of cards)	6.71%
Average delivered horse power (useful work)	747.785 HP.
Average Ind. horse-power, H.P. cylinder	292.057 "
" " " I. P. "	248.773 "
" " " L. P. "	260.739 "
Total	801.569 HP.
Average moist steam per I. HP. per hour	10.479 lbs.
Average dry steam per I. HP. per hour	10.335 "
Average B. T. U. per I. HP. per minute	196.080 B. T. U.

Coal and Rate of Combustion and Evaporation.

Total coal burned, 24 hours	19,612 lbs.
Coal burned per sq. ft. of grate surface, per hr.	12.793 "
Coal burned per sq. ft. of heating surface, per hr.	.287 "
Evaporation per lb. of coal, actual conditions, including economizer	10.472 "
Evaporation per lb. of coal, actual conditions, excluding economizer	9.785 "
Evaporation per lb. of coal, from and at 212° F., including economizer	12.478 "
Evaporation per lb. of coal, from and at 212° F., excluding economizer	11.660 "
Evaporation, actual, per sq. ft. of heating surface, per hour	3.00 "
Coal, per I. HP., per hour	1.62 "
Coal, per delivered HP.., per hour	1.69 "
Coal burned in 24 hours, for fan, stoker and economizer engines, as determined by subsequent test	800 "
Total coal burned if boiler supplying steam for test had supplied steam to fan, stoker and economizer engines	20,412 "

Duties.

Duty per 1,000 lbs. moist steam, deducting plunger leakage (contract basis)	176,051,500 ft. lbs.
Duty per 1,000 lbs. dry steam, deducting plunger leakage	178,497,000 "
Duty per 1,000,000 B. T. U.	157,002,500 "
Duty per 100 lbs. coal, making allowance for coal required for supplying steam to fan, stoker and economizer engines	173,869,000 "

Efficiencies.

Efficiency of mechanism	93.29%
Efficiency of boiler and economizer, actual	85.9%
Efficiency of boiler alone, actual, if economizer had not been used	80.3%
Thermal efficiency of engine	21.63%

A DEFENCE OF AUSTRALIAN HARDWOOD PAVEMENTS.

In our issue of May 31 and June 21, 1900, there were included a note and letter respectively in relation to the comparative durability of wood and asphalt pavements in London. The note was an abstract of a report on the subject, prepared by Mr. D. J. Ross, City Engineer of (old) London. Mr. Ross favored asphalt, and in the course of his report made some disparaging remarks on Australian hardwood pavements under his supervision and outside the city proper. These remarks were taken as a challenge by Sir Edward H. Wittenoom, Agent-General for Western Australia, who speedily caused the publication of a reply, in pamphlet form, from which we have made the following abstract:

Mr. Ross stated in his report that of the 15 streets in the city proper laid with Australian hardwood all were in "good" or "fair" condition except two, which showed "signs of wear." He added that "the length of time they have been down is not sufficient to warrant any opinion as to their durability being given," and then proceeded to review the experience with hardwood

on streets "outside the city." The report in rejoinder to Mr. Ross states that all the streets named by him "have been inspected and the surveyors of the districts in which they are situated have been seen in regard to them with the following results." While the "results" as reported are partisan in character they contain so much matter of general interest, as well as all that is given on the particular subject in question, that we quote this section of the report nearly in full:

Tottenham Court Road.—This road was laid with Jarrah in 1892 by the St. Pancras Vestry. The work was done under the supervision of the present surveyor, Mr. W. N. Blair, M. Inst. C. E., who at the time had just taken office, and who had, therefore, to carry out the work in accordance with conditions previously determined. Respecting this road, Mr. Blair says that the material supplied was not quite satisfactory, as many of the blocks were not true to gage. They were described in the contract as "cut from the deals as imported," and in thickness they varied as much as ¾-in., consequently it was impossible to lay an even pavement. Nor, in the light of subsequent experience, does he consider that the blocks were as efficiently laid as they might have been. The condition of the road after eight years' wear is certainly not good, as through the crowning or buckling of the blocks it has become very rough and "corduroy" in its character. This, however, does not affect the durability of the material, as without doubt many, if not most, of the blocks could be turned and used again. Since 1892 Mr. Blair has laid many thousands of yards of Jarrah and Karri wood in his district, and with uniformly excellent results. In referring to St. Pancras, this fact might have been noted by Mr. Ross. Mr. Blair appears to have studied the method of laying wood blocks most carefully. The result of his experience and observations, therefore, in regard to the suitability of hardwood paving and to the best methods of laying the wood will be of interest. He lays his blocks with ⅛-in. joints, in which he places small deal laths, the joints being then carefully grouted with pitch. By this means the expansion and contraction of the wood are provided against. In no case, the surveyor says, has the expansion of the blocks given him any trouble by the displacement of kerbs and footways, as so frequently occurs where cement grouting is used. Exceptional contraction is corrected by running in the joints affected with pitch. The durability of hardwood paving in this district is unquestionable, and, in view of the traffic in Euston road and other great thoroughfares, its suitability for streets with heavy traffic, when well laid and carefully supervised after laying, is clearly demonsfrated.

St. Paul's Road, Canonbury.—This road was laid with Jarrah in 1894, for the Islington Vestry, by the Improved Wood Paving Co. The blocks were laid on a 7-in. concrete bed, without floating, as, in the opinion of the surveyor, Mr. J. Patten Barber, M. Inst. C. E., the concrete in this instance did not require it. The paving work appears to have been well done, and, though the blocks are rough in the center of the road, where nearly all the traffic passes, they seem but slightly worn. Mr. Barber, who is a recognized authority on paving, gives very close attention to his roads, and has had considerable experience with hardwoods. In his district, as in St. Pancras, they have been used extensively and with excellent results. The method of laying adopted by Mr. Barber differs from that of Mr. Blair, of St. Pancras, and is more in accordance with the usual custom. He dips his blocks in pitch and close joints them, grouting with pitch. He corrects the expansion and contraction of the wood by careful supervision after laying. The expansion joints adjoining the kerb are carefully watched, and when they are becoming nearly closed, but before the blocks begin to press on the kerb, the expansion joint is widened. In this way no kerb has been pushed out of place by the expansion of the wood in this district. As soon as the blocks show signs of contraction they are carefully watered, so as to prevent the joints opening and the blocks becoming loose. Occasionally the roads are drenched with water at night, which not only helps to prevent contraction, but cleanses the roads.

Regent St., Piccadilly, Shaftsbury Ave. and (presumably) Pall-Mall East.—As three of these streets belong to one vestry (St. James', Westminster), and all of them have been paved with one class of hardwood (Karri), they may be taken together. In an enquiry here, the surveyors (Mr. Henry Monson, Assoc. M. Inst. C. E., of the St. James Vestry, and Mr. G. Green, Assoc. M. Inst. C. E., of St. Martin-in-the-Fields) kindly supplied the information required. Regent St. was laid in 1897, for the St. James' Vestry, by Mr. Griffiths, contractor, and the work was most carefully done. The same may be said of Piccadilly, which was laid in 1896 by the Improved Wood Paving Co. In these streets the wood has evidently shrunk and swelled, so that the courses have become irregular, resulting in an uneven surface and in the loosening of many of the blocks. In Shaftesbury Ave., which was laid in 1897 by Mr. Griffiths for the St. James' Vestry, the objection arises partly from the roughening of the wood; but in Pall-Mall East, laid in 1896 by the Vestry of St. Martin's, it clearly arises from the unusual shrinkage of the blocks. In each of these cases there is certainly good ground for complaint, but it should be noted that, while the wood used is Karri only, which in these instances has expanded and contracted considerably, Jarrah, and, indeed, all woods, are subject in a measure to the same conditions.

Rosebery Ave.—The portion of hardwood paving in this Ave. to which Mr. Ross refers, was laid in 1896 by the Clerkenwell Vestry. The wood used was Jarrah, and it was laid with a cement grout. Mr. P. G. Killick, the surveyor, says "in dry weather the blocks have got rather loose, the courses have also become rather irregular in places. I do not consider cement grouting suitable for hardwood paving. Spencer St., which was laid by Mr. Griffiths, was paved with pitch grout in August, 1895, and I have not had to spend a penny in repairs. We have just paved the second portion of Rosebery Ave. with Jarrah wood, close joint, hand dipped, and pitch and tar grout, area about 4,000 yds., and are about to pave Lower Charles St., 1,150 yds., and Percival St., 2,150 yds., with similar wood and grouting."

Kensington.—Mr. Ross states that in this district the surveyor, Mr. W. Weaver, C. E., had used hardwood, but was removing or had removed, substituting deal blocks for it. The reason of his doing so, however, does not touch the question of the durability of the woods, and therefore it is difficult to see why this district was introduced. Mr. Weaver found that a small section of Jarrah which he had laid expanded much more than deal, between which it was laid, and he contended that it was, in consequence, likely to prove less satisfactory if used on a large scale than the wood he was accustomed to employ. But, in treating of this district, it should be borne in mind that the surveyor is an authority upon and the special advocate of creosoted yellow deal, which he has used with advantage for a number of years. It is not to be inferred, therefore, for a moment that he has not given the hardwood a fair trial, for Mr. Weaver is one of the most careful and capable authorities on paving, but the trial is, apparently, a very limited one, and will not compare with those of the other disfricts under review.

Each of the cases cited by Mr. Ross has now been examined and reported upon, and it has been shown (1) that Karri is the wood used in 4 of the 7 streets to which he refers, and that the chief objection to this wood in Regent St., Piccadilly, and Pall-Mall arises from its liability to expansion and contraction—a satisfactory, if not complete, remedy for which may be found in an efficient and proper system of laying, and in careful supervision after laying; (2) that in St. Pancras (Tottenham Court road), Islington (St. Paul's road, Canonbury), and Clerkenwell (Rosebery Ave.), the examples of unsatisfactory hardwood paving given are clearly exceptional, as is shown by the extensive and successful use of this paving in other parts of the same districts; and (3) that so far as the durability of hardwood for paving purposes is concerned, the examples cited do not bear out Mr. Ross' contention, that "this class of pavement is not of that durable nature anticipated."

After discussing the relative merits of asphalt and wood pavements in some detail, the conclusion is reached that:

If two streets, similar in position and traffic, were laid, the one with wood and the other with asphalt, and the material used, the method of laying, and the supervision (including cleansing and repairs) were, as far as possible, of the same character, there is no question that for ordinary paving purposes, and even for durability, wood, especially hardwood, would prove superior to asphalt.

The next section of the report is devoted to brief reviews of the experience or opinions of some fifty surveyors for as many London vestries and English provincial towns, most of which have tried hardwoods and are in favor of them, although a few prefer soft wood for pavements. The report concludes as follows:

The following is a summary of opinions in regard to the character of Western Australian hardwoods and the methods of laying hardwood paving:

Methods of Laying.—In a large number of instances the blocks are laid close, dipped in pitch and grouted with pitch. By pitch is usually meant a composition of pitch and tar. In some cases, one side and one end of each block are dipped, and in others the bottom half of the block is dipped. Some excellent results have been secured by laying the blocks dry and carefully grouting with pitch, and by dipping in pitch and grouting with cement and sand. The borough surveyor of Leicester, Mr. Mawbey, tried four methods of laying: (1) with ¼-in. joint, (2) with 1-16-in. joint, (3) with close joint—all grouted with cement and sand—and (4) with close joint grouted with pitch. He states that he finds the last to be much the best method.

Size of Blocks.—Some surveyors believe that a better pavement would be made with blocks 7 or 8 ins. in length than with the customary 9 ins., as the camber of the road would be better preserved and the blocks be kept more even. Opinions vary considerably as to the depth of the blocks. Many surveyors who formerly used 5 ins. or even 6 ins. are now using 4½ ins., and some 4 ins. It is thought by some, however, that a depth of 4 ins. does not afford a sufficient "key."

Buckling of the Blocks.—It is considered that the crowning or buckling of blocks is largely due to the difficulty of making and keeping an even pavement, the remedy for which lies mainly in efficient laying and in careful supervision.

Slipperiness of the Blocks.—It is found that when the blocks are kept clean and in bad weather are carefully sanded, there is very little cause of complaint as to their slipperiness. The comparison in this respect with asphalt is all in favor of wood.

Soft Wood versus Hard.—It is stated that, for paving purposes, soft wood has an advantage over hard, because it affords a better foothold for horses, and makes, on account of its "burr," a more even pavement. But it is universally acknowledged that among the advantages which hard wood possesses compared with soft are the following: (1) It is more durable; (2) it absorbs less moisture and dries more quickly; (3) it is, therefore, less slippery, especially when the soft wood becomes greasy; (4) it gives off less dust in dry weather; (5) its sanifary character, a matter of great importance, is, in consequence, far superior, and (6) it is less costly to keep clean.

General Conclusions.—The particulars given in this report and the general evidence on the subject prove that, in the judgment of a very large number of experienced surveyors, Western Australian hardwood blocks, well cut, true to gage, laid on an efficient system, and carefully supervised both during and after laying, constitute for city and suburban thoroughfares the best paving known.

EXPERIENCE WITH MECHANICAL SCRAPERS FOR CLEANING WATER MAINS AT HALIFAX, N. S.

Cast-iron water mains were cleaned by mechanical scrapers at Halifax, N. S., in 1898, to the aggregate length of 112,803 ft. The mains ranged from 24 to 3 ins. in diameter; 6,712 ft. of 20-in., and 29,628 ft. of 15-in. pipe, out of the total, were cleaned the second time, the balance being cleaned but once. The total cost of this work was $449, or an average of about 0.4 cts. per ft., regardless of size. Nearly one-third the total cost, or $133, was due to cleaning 3,565 ft. of 6-in. pipe, which was so thickly encrusted that it stopped the scraper several times, making it necessary to cut the pipe. This pipe had not been scraped before since 1890, when the cost was only $10.93. In 1887 it was cleaned at a cost of $19.82; in 1884, 1,425 ft. of length was cleaned at a cost of $6.75. In 1882 was all cleaned, costing $247.11, but this includ the construction of hatch-boxes for inserting t scrapers and contingent expenses. The date of l ing this main is not given. The total expendit for cleaning this one 6-in. main, including t initial outlay for hatch-boxes and accessories, l nothing for the scrapers, has been $417 for the 1 years, 1882 to 1898, inclusive. This is a average of $24.50 per year, or about 0.7 cts. p lin. ft. The aggregate length cleaned on this s tion was 15,685 ft. (four full and one partial scra ings, giving an average cost of 2.7 cts. per traveled by the scraper. These facts have be taken from the last published report of Mr. F. W. Doane, City Engineer of Halifax.

The report (1898-9) contains detailed records the mains cleaned from 1880 to 1898, inclusi... Mr. Doane calls attention to the low cost of this work, in a number of instances, as follows:

We have been using a mechanical scraper in our water mains since 1880, and at times have performed the work at very low cost; for instance, you will see on reference to the statement, that in 1884 the low-service 24-in. main, 13,400 ft. in length, was cleaned for $8.23, being 0.06 ct. per lin. ft. In 1885 the high-service 15-in. main, 29,628 ft. in length, was cleaned for $8.30, or 0.03 ct. per lin. ft. In 1898, this main, with the 20-in. main, 6,712 ft. in length, was cleaned for 0.04 ct. per lin. ft., the work being performed on the same day, necessitating the passage of two scrapers of different sizes and the removal and reinsertion of a reducer at their junction. We clean our 15 and 20-in. high-service mains twice a year, as we need every pound of pressure that we can get from it.

According to the report, Kennedy-Keating scrapers are used at Halifax. In our issues of July 20 and 27, 1899, we published an article entitled "Cleaning Cast-Iron Water Pipe with Scrapers at St. John, N. B., and Boston, Mass." We gave, in the issue first named, a list of articles on the general subject which have appeared in Engineering News and other technical publications since 1880.

THE INCREASED POWER OF LOCOMOTIVES of modern construction over those of older date is evidenced by a statement in the report of the Chicago & Northwestern Ry. for the year ending May 31, 1900. During the year 82 locomotives were purchased, in replacement of a similar number retired from service. These 82 locomotives are equal in tractive power to 203 locomotives of the class they have replaced, the increase in such power being 147½%.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXI-XXIII. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

The South Pass jetties, by which a deep-water channel was created at the mouth of the Mississippi River, have long been among the most famous of American engineering works. At the time of their construction they were fully described in such engineering literature as existed at that day; but since their completion, over a score of years ago, little has appeared in print concerning their operation save the annual official reports, a source of information of which few engineers can avail themselves.

We present to our readers in this issue an article describing experience with the South Pass from the pen of Major Wm. Starling, one of the members of the board which recently reported in favor of the improvement of the Southwest Pass outlet of the Mississippi as a deep-water channel. In this paper Major Starling tells in a succinct manner the story of the work which has been done year after year in the South Pass in the attempt to maintain the channel, and describes the causes which have operated to bring about the deposit of over 13,000,000 cu. yds. of silt in the pass and its final shallowing to such an extent that it no longer meets the demands of commerce:

"I wish you would give less space to the description of new things and more to telling us how the old ones actually worked," was the substance of a letter once received at this office. The editors are well aware of the value of this class of engineering literature, and aware also of the difficulty of securing it. It is undoubtedly of the greatest value to learn the results of experience, and find where engineering devices and expedients have failed as well as where they have succeeded. Major Starling's paper belongs to this class of engineering literature; and in view of the fame of the work whose recent history it records, will be, we are sure, thoroughly appreciated by our readers.

It is not many months since the head of the Health Department of New York city astonished the world by the published statement that the "vapors" arising from the asphalt pavement when exposed to a hot sun were one of the chief causes of the prevalence of disease. Last week the public was treated to some further gems of technical knowledge from New York officials. The first specimen was furnished by Mr. Hawkes, Superintendent of Water Distribution and Repairs, who was interviewed by a reporter concerning the alleged failure of the department to hasten the introduction of water meters in Brooklyn. According to the "Tribune" of Aug. 16, Mr. Hawkes replied as follows:

> In all applications for ⅝-in. taps we compel the insertion of a meter. In the placing of a ⅜-in. tap the meter is unnecessary, for the consumer can hardly waste more water than he pays for under our system.

We cannot help wondering whether Mr. Hawkes is aware how much water can be wasted through a ⅜-in. tap. If the pressure is really so low in Brooklyn that no more water will flow through such an opening than what the fixture rate will pay for, then it is high time the fire underwriters got together to cancel policies and advance rates.

The pearl of the collection, however, is the following deliverance on filtration. We quote from the "Tribune" of Aug. 16 as follows:

WATER FILTRATION IMPOSSIBLE.

Whole System of Pipes Would Have to be Changed to Purify Supply.

The specifications for the filtration plants which are to be erected on Long Island at Baisely's and Springfield's ponds are now in the hands of the printer. It is expected that they will be made public by the end of this week.

At the time it was thought that the plants to be erected would lead eventually to the filtration of the entire water supply of the city of New York. But that this is not likely to be the case is made plain by the fact that the water supply of Manhattan is carried in lead pipes. Filtered water in lead pipes would lead to greater evils than those from which the city at present suffers. At the office of Water Commissioner Dalton yesterday it was said:

> It would be out of the question to attempt to carry filtered water through lead pipes. To introduce filtered water into New York would involve the laying of an entire new pipe system, an undertaking which makes filtration, so far as Manhattan is concerned, impossible, and, in fact, preposterous. The present water supply of the city is kept clean by homœopathic methods. The pipes are coated with layers of slime. In this slime all the dirt passing through the pipes is caught and lodged. This deposit of slime has a frightful odor, as might be expected, and the pipes are filthy beyond description, but it is this very filth which purifies and cleanses the water. Now, to change this without changing the material of which the pipes are made would mean, at least, the scraping of this slime from the pipes. Then the filtered water would be turned in. With what result? Instead of bits of dirt there would be little flakes of tin, and instead of occasional biliousness we should all have tin poisoning. This is no exaggeration. Filtration for the whole city is simply impossible, as was said before. No city in the world has a complete system of filtration. What is more, filtration is never used where the water supply is furnished through tin pipes.

We trust those misguided individuals who have sought to persuade the public that pure water is better than foul water, and that filtration of public water supplies is important to the preservation of public health, will take warning and cease from their nefarious labors. In the light of the above statement it is truly better to "bear the ills we have than fly to others that we know not of." Surely it is better to endure "occasional biliousness," "bits of dirt," "layers of slime," and other accompaniments of what is elegantly designated as the "homeopathic method" of purifying the water supply rather than run the risk of having our whole insides coated with a bright and glittering layer of tin. What pleasure would there be in pouring the drinks for which New York is so justly famed down a tin-lined throat and over a tin-lined palate? One might as well turn them into an eave-spout.

Commissioner Dalton is in charge of the water supply of the greatest city of America, and receives a salary of $7,500 a year. Of course, therefore, he knows all about a little thing like filtration, and it is lucky he warned us in time. If the water is bad let us drink beer or drown the "bugs" by diluting with Kentucky rye.

We are sorry to say, however, that the above official utterance on filtration contains one palpable error of fact. It is said that no city in the world has a complete system of filtration. Now it is unfortunately the case that nearly all English cities (to say nothing of many in other lands) have and have had for years complete systems of filtration. How can we reconcile this with Mr. Dalton's metalliferous theory? Can it be true that the fiery Scotch whiskey, which is a common beverage on the other side of the water, is rendered a pleasant and soothing concoction by the possession of triple-plated throats? Or can the remarkable stiffness of some of our British cousins be explained by the existence inside them of a complete system of block-tin plumbing? We trust the experts of the New York water department may enlighten us further on these questions.

Elsewhere in this issue we print a detailed description by Prof. R. H. Thurston of the Nordberg pumping engine installed at Wildwood, Pa., together with full drawings furnished to us by the builders showing its construction.

The notable feature of this engine is its unrivalled economy as a heat engine. It shows in operation an efficiency of about 75% of that theoretically possible with a perfect engine working between the same limits of temperature and about 5% greater than the efficiency of any other engine ever built. This remarkable performance is credited largely to the peculiar system of feed-water heating employed, by which steam taken from the cylinders, intermediate receivers and jackets, is used in heaters to raise the feed-water by successive steps nearly to boiler temperature. That the credit is justly placed is shown by the fact that the consumption of thermal units per HP. hour rises more than 11% when these heaters are not in use. Although other engines have shown greater economy as measured by the weight of steam used, this engine holds the record of taking from the boiler the least amount of heat per HP. hour.

The system of heating feed-water in separate stages is one method of improving the economy of the steam plant, and in the case of the Nordberg engine this method has been remarkably successful. Another method is that of using economizers to utilize some of the heat of the escaping flue gases to heat the feed-water; a third method is the use of superheated steam, and a fourth method is the use of some of the heat of the flue gases to heat the air used for burning the coal in the furnace. All four of these methods have been tried, and all have shown certain advantages. It would seem possible to use two, three, or even all four of these methods in combination, with the result of obtaining a considerably lower figure for fuel consumption than has ever yet been obtained.

For marine equipment the method of feed-water heating used in this Nordberg engine might be especially advantageous. While economizers are excluded from a ship because of their size and weight, the extra weight incident to this system of feed-water heating is comparatively small. In fact it might be greatly counterbalanced by the saving in weight in the low pressure cylinders of the engine, since an engine of a given power using this cycle would have slightly larger high-pressure cylinders and considerably smaller low-pressure cylinders than an ordinary multiple expansion engine. Feed-water heaters may be attached to existing engines with only slight alterations, as has already been done in Europe.

The commercial importance of increase in engine efficiencies becomes less with each successive increase. This is because such increase usually entails greater first cost of engine and also because with high efficiencies the cost of fuel is relatively a small part of the total cost of producing power. The interest attaching to exceptional engine performances is largely scientific. In the present instance there is an added interest due to the engineering ability exhibited in the excellent design, as shown in the description by Prof. Thurston.

In this issue we also give a report of a recent trial of the new Allis triple expansion pumping engine, at the Chestnut Hill station of the Metropolitan Water-Works, Boston, Mass., which shows a record of 157,002,500 ft.-lbs. per million B. T. U.

and 1.02 lb. coal per I. HP. per hour. An economizer heated the feed-water from 79.72° to 154.98° F. It would be interesting to know what record would be obtained by this engine if it were to use the Nordberg system of heating feed-water referred to above.

THE WATER WASTE AND FUTURE WATER SUPPLY OF GREATER NEW YORK.

Two remarkable reports on the water supply of Greater New York have been published within the past few weeks. One of them, due to the energy and public spirit of the Merchants' Association, is just from the press, and to it we devote a large amount of space this week. The other report, made by Mr. John R. Freeman, M. Am. Soc. C. E., for Mr. Bird S. Coler, Comptroller of New York city, was published a few weeks ago.*

These two reports should awaken New York city to the fact that it is in danger of a most disastrous water famine unless active, immediate steps are taken to secure a greater margin between the rapidly increasing demands for water and the available supply. The reports should also arouse New York to a realization of the enormous waste of water now permitted in every borough, but particularly in Manhattan and the Bronx. Nor should the effect of these reports stop with New Yorkers, for they show that many other cities, in fact most of the larger ones, are wasting water even more recklessly than New York.

This extravagant waste of water, in the case of New York, gains added significance from the fact that much of its future water supply must be filtered. Mr. Freeman advises all plans for a new supply to provide for the future installation of filter plants. The Merchants' Association includes immediate filtration in all but one of its estimates for a new supply, and recommends filtration of all that part of the present supply which is drawn from surface sources. These statements and recommendations regarding both waste prevention and filtration are in thorough accord with the best engineering practise and municipal administration of the day.

The two watchwords of the future, in matters of public water supply, will be WASTE PREVENTION and WATER PURIFICATION. Unfortunately many engineers, more water-works superintendents and the great mass of the general public still ignore their importance.

It was pointed out a number of years ago, by Prof. W. T. Sedgwick and others, that the American people as a whole have placed quantity above quality in developing public water supplies.

Some of the cities of the United States with the most notoriously bad water supplies have only recently ceased boasting of their enormous water consumption. Among this number are Philadelphia, Pittsburg and Allegheny. The first two of these are now working in good earnest to introduce filtration, but while Pittsburg has voted money for the restriction of waste as well as for purification, Philadelphia persistently refuses to take efficient steps to cut down a water consumption and waste of 200 gallons per capita.

In the light of the Philadelphia figures, the 103 gallons per capita used by all New York in 1899, and the 117 gallons by Manhattan and the Bronx, seem modest indeed; but one has only to refer to the studies of Messrs. Freeman, Croes and Crowell, the two last for the Merchants' Association, to see that half or more of this is sheer waste. It would be difficult to present this more graphically than is done by the accompanying diagrams from Mr. Freeman's report. It will be remembered that in his preliminary report Mr. Freeman published a diagram (see Eng. News, April 19) showing the day and night draft on the Croton supply for a period of a week, as determined by careful gagings of the delivery of water to old New York. Since then he has made similar gagings for the Brooklyn supply, and has secured others for Fall River and Woonsocket, two cities notable for thir use of meters and their low water consumption.*

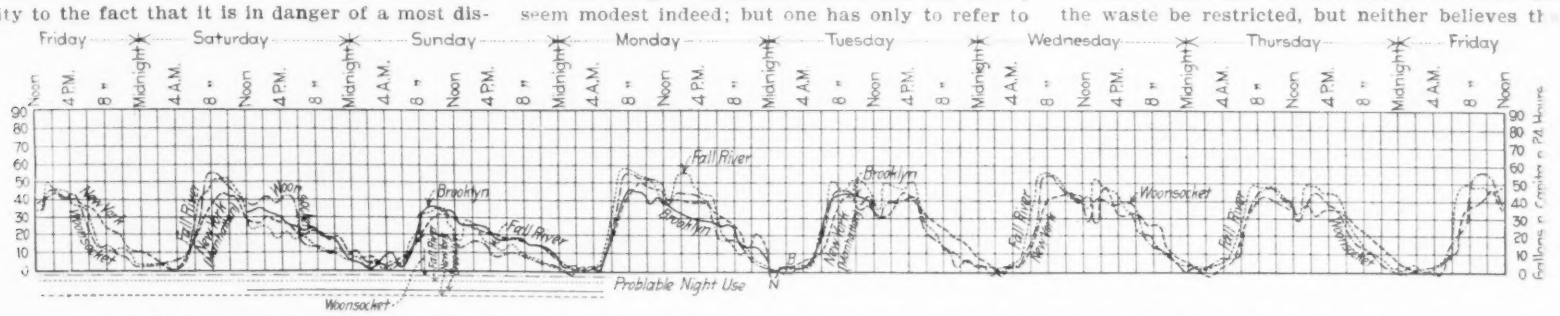
It will be noted that the hourly consumption in old New York is never below a rate of 90 gallons per capita per day, while Brooklyn goes down to about 65 gallons and the other two cities to 5 gallons, minimum. More significant than the actual gagings are the curves showing the excess of day over night consumption in the four cities. As to these curves, Mr. Freeman says:

> This very remarkable agreement indicates that the amount of water per capita really used in Manhattan and Brooklyn is not very different from the amount used in the completely metered cities of Fall River and Woonsocket, and the closeness with which the New York and Brooklyn curves follow one another confirms the accuracy of these entirely independent measurements.*

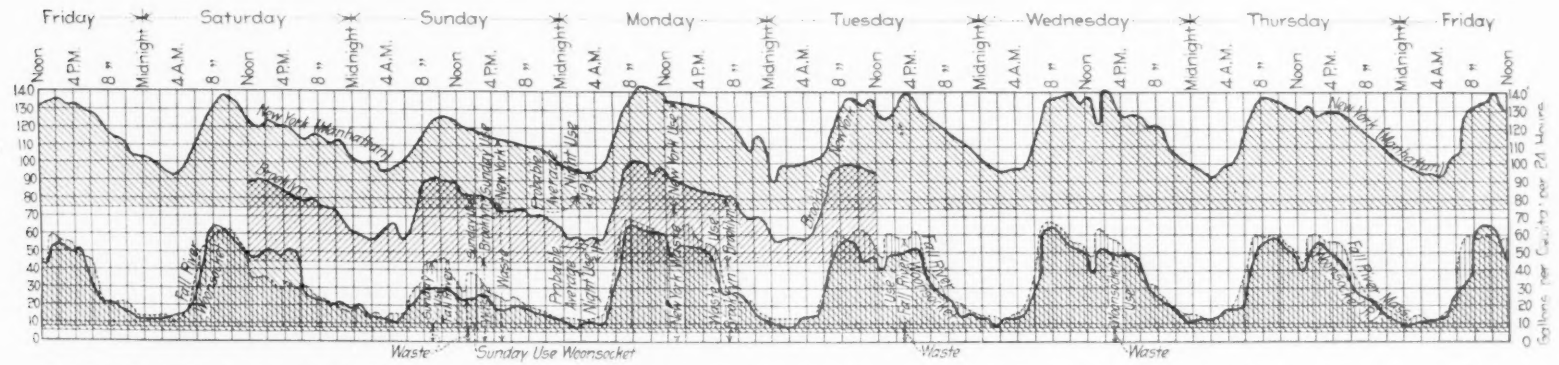
If after studying these diagrams the reader will refer to the abstract in this issue of what Messrs. Croes and Crowell say regarding the waste of water in New York city, we think the enormity of water waste, both in New York and in unmetered American cities generally, will be impressed upon them as never before.

Perhaps some of those who have read the two reports in full or in abstract will ask: "How can Mr. Freeman and the engineering committee, in the face of all these facts as to waste, recommend that Greater New York immediately develop some 500,000,000 gallons daily additional supply? If half the supply is wasted, why not cut down the waste instead of encouraging it by providing vast additional supplies?" The first answer to these hypothetical questions is that both the engineering committee and Mr. Freeman do recommend that the waste be restricted, but neither believes that public opinion and city administration in any American metropolis can be trusted to carry out measures of waste restriction that will more than tide over the period needed to plan and construct new works. As engineers, all these gentlemen see the evil and the remedy, but they also see a solid wall of opposition, indifference, and perhaps worse, between the evil and the remedy. Mr. Croes, however, in his report to the engineering committee, makes a courageous stand in favor of relying on waste restriction to maintain the adequacy of the Croton supply for old New York until 1950. The engineering committee records its disbelief in any such possibility. It says that the conditions "seem to us to point towards a legitimate and desirable increase of supply per capita." This opinion seems to conflict with its earlier recommendation that a reduction of waste by the extension of the meter system can and should be effected; but perhaps the intent is to suggest a curtailment of waste and an increase of use, one to offset the other.

The engineering committee lays much stress upon the fact that Greater New York has a lower per capita water consumption than other large American cities. It also urges that the experience of foreign cities, and likewise of American cities



EXCESS OF DAY OVER MINIMUM NIGHT CONSUMPTION (OR OF HOURLY OVER MINIMUM HOURLY RATE PER 24 HOURS).



DAY AND NIGHT CONSUMPTION AND WASTE OF WATER IN NEW YORK, BROOKLYN, FALL RIVER AND WOONSOCKET, REDUCED TO GALLONS PER CAPITA PER DAY.

From Report of John R. Freeman, M. Am. Soc. C. E.

HOURLY VARIATION IN CONSUMPTION AND WASTE.

(The New York observations were made from Dec. 8 to 14, 1899, and the Brooklyn, April 21 to 24, 1900, both under the direction of Mr. Freeman. The other observations were from April 25 to May 2, 1900; those at Fall River were made by Mr. P. Kieran, Superintendent of Water-Works, and those at Woonsocket by Mr. B. I. Cook, Superintendent of Water-Works.)

*A preliminary report by Mr. Freeman was issued last spring and abstracted at length in our issue of April 19.

*The original diagrams included curves for Providence, R. I., based on four days' records made in June, 1891, which we have omitted for the sake of greater simplicity and comparability.

*This diagram is constructed from the diagram of the use and waste by first drawing a datum line on the curve of consumption for each city through the average of the points of minimum consumption, then tracing the curve with this line as a common zero line.

which have adopted the universal meter system, is not applicable to New York. It seems to us that Mr. Freeman's diagrams, reproduced herewith, are pretty good evidence that the full meter system in New York, combined with the gradual reduction of underground leakage, would cut down the preventable waste to such an extent that the real use and the incurable waste combined, plus a legitimate increase in consumption, would place New York still lower down in rank among the great cities of this continent. The population and the industries of New York have reached such enormous proportions that any legitimate increase in the use of water by one class of either population or industry has but a very small effect on the average per capita consumption. In the better class of residences there is little if any chance for a legitimate increase in the present consumption per capita. In the poorer residences and tenements there is undoubtedly an opportunity for a legitimate increase in use, but this increase is likely to be slow, because both landlords and tenants are backward in securing the additional plumbing fixtures necessary to that end. It is probable that if the facts could be known it would be found that the increased draft of water following the addition of new plumbing fixtures in houses already supplied with water is to be laid quite as much to multiplied opportunities for waste as to actual use. Leaky fixtures and faucets constantly running often waste far more water than is really used. It is highly desirable that the facilities for using water be increased in most of the crowded sections of the city, but if this were done on metered buildings, so each new faucet was not one more unchecked source of waste, the effect on the draft of water in such buildings would be less than is generally supposed, while the total result from thousands of buildings might scarcely be reflected in the per capita consumption of the whole city. If, on the other hand, the number of faucets in unmetered tenements should increase largely it is probable that the waste would be appreciable. It should be remembered that increased use is commendable and desirable, but every gallon of preventable waste is to be deplored, while an increase in the present enormous waste of water in Greater New York would be almost criminal.

Both Mr. Freeman and the engineering committee recommend immense new works capable of delivering hundreds of millions of gallons in addition to the present supply. Mr. Freeman advises that the Housatonic and Ten Mile River be chosen, while the engineering committee reject both this and the Wallkill (the latter recommended by Mr. Fuertes), and propose the Hudson River, either at its head waters, or at Poughkeepsie; the water to be filtered and pumped, in the latter case. The engineering committee places the Housatonic first and the Wallkill second, in order of economy, but rejects both on the advice of the legal committee, on account of possible interstate complications. If a big new supply is to be developed, we confess a strong leaning towards the Housatonic, so far as the evidence at hand goes. We agree with Mr. Freeman in believing that the legal difficulties might be overcome by proper business methods. At least the feasibility of securing the necessary rights from the State of Connecticut seems to be well worth further investigation. On the other hand, there is much to be said in favor of the Hudson at Poughkeepsie, whenever it is found necessary to go beyond the Croton and Long Island drainage areas, and the minor area easily rendered tributary to the Croton, particularly as this scheme would fit in readily with a rigid policy of waste restriction, and thus a husbanding of the present sources of supply.

As an engineering and business problem, Mr. Freeman goes far towards admitting that the Croton, Bronx and Byram, might be made to suffice for Manhattan and the Bronx (old New York) for many years to come, by cutting down the enormous waste of water in those boroughs. His Brooklyn gagings, combined with those made at Fall River and Woonsocket, and his comments on the diagrams reproduced herewith, indicate that at least a temporary margin might be created in the Brooklyn supply by cutting down waste and carrying out the works planned long ago to make available water now going to waste. But in view of local conditions, Mr. Freeman credits the possibilities of waste restriction with merely affording a means of tiding Greater New York over its danger point, pending the development of a new supply. The engineering committee, we think, is more consistent than Mr. Freeman in its attitude towards waste; but this is not saying that we approve its conclusions. Mr. Freeman has developed, through statistics and diagrams, all based on painstaking investigations, one of the most thorough, instructive, and we may say beautiful, demonstrations of water waste and the relatively small amount of water used, that was ever presented to the engineering profession. To see the advantages of such a demonstration nullified or abandoned, for fear of the impossibility of overcoming administrative inertia, and popular prejudice is a cause for regret, even if the abandonment is deemed unavailable, which is open to question. The engineering committee, on the other hand, throws down, or virtually discredits, the conclusions of its engineers, Messrs. Croes and Crowell, which closely parallel those of Mr. Freeman. It admits that there is waste, and that it can and should be reduced, but it never admits the possible wonders that might be effected by its reduction, so ably set forth by Mr. Freeman and Messrs. Croes and Crowell.

Now, might it not be well worth while for Greater New York to consider carefully the advisability of spending in waste restriction only a fraction of the enormous outlay involved in either Mr. Freeman's Housatonic, or the engineering committee's Hudson River scheme, and the possibility of thereby postponing the necessary date for an immense new supply of water? By turning the Ten Mile River into the Croton drainage area, a proposition made many years ago, and renewed from time to time since, the full capacity of both aqueducts might be utilized, and this additional supply would assume greater relative proportions than now if the waste were cut down. Likewise, something might perhaps be accomplished for Brooklyn or Long Island, although Mr. Croes recommends an immediate large new supply for that borough. Under this plan of waste restriction, the Hudson at Poughkeepsie, when finally needed, would seem to be far preferable to the Upper Hudson, since it could be made available in comparatively small instalments, whereas the Upper Hudson, or the Housatonic, must be developed on a huge scale, to be most advantageous. It should be noted, perhaps better right here than elsewhere, that the general committee of the Merchants' Association recommends a new supply of only 250,000,000 gallons a day to be taken from either the Upper or Lower Hudson.

Two important points we wish to especially emphasize in concluding: (1) If waste restriction is inexpedient as a means of relief from the almost imminent danger of water famine suggested by Mr. Freeman, and certainly not disputed by the engineering committee, what chance is there of cutting down waste with an additional supply of 250,000,000 to 1,500,000,000 gallons in sight? (2) Even though it be true that the vast schemes recommended in these reports for immediate or future adoption involve only a small annual per capita expense, the requisite increase in bonded indebtedness is no such light matter. Greater New York has many other pressing needs besides those pertaining to water, and is very close to its bonded debt limit. Although it may issue all the bonds it chooses for water-works outside the limit, it cannot subsequently issue bonds for any other improvements until it again gets within the limit. If a constitutional amendment be secured, as proposed by the water supply committee, so as to remove all relation between the debt limit and water-works bonds, there will still be reason for questioning the financial wisdom of incurring so large an indebtedness if it is probable that all the real needs of the city can be fully met by a relatively small increase. Then, too, the New York Board of Health has recommended that the Croton water be filtered, and the engineering committee endorses that advice and extends it to the whole supply. As we have already intimated, waste prevention and water purification go together.

Finally, Mr. Freeman and the water supply committee (with Controller Coler and the Merchants' Association as their respective backers), and the citizens of New York and lovers of good government generally, are to be congratulated upon the manner in which the Ramapo water snake has been scotched. It is to be hoped that it will join the shades of the Schuylkill water snake at Philadelphia; but we must confess that we shall feel less apprehensive for each city when it has obtained for itself an ample supply of pure water, either by developing new or conserving and purifying present sources of supply.

LETTERS TO THE EDITOR.

A New Method of Attaching Brakes to Car Trucks.

Sir: We notice in Engineering News, of Aug. 2, an extract from the "Brake Test Report" of the New York State Railroad Commission. The device we submitted in these tests does not receive a proper classification in this report.

We take the brakes, beams, levers and rods that are at present hung from the truck frames, and therefore upon the springs, and we hang them upon our "brake equalizing bars," which rest upon the axle boxes, and in place of filting the truck frames every time the shoes are applied to the wheels, we maintain the frames in a horizontal plane, no matter how severely the shoes are applied.

Our device increases the efficiency of the foundation brakes and is a valuable factor in any method of braking that may be used, whether air friction, electricity, or hand. The report entirely fails to list our device under any one of the heads, such as air, electricity, etc., the only explanation is that we submitted a "method of levers," yet we made every stop in less time than all the others and did it with a hand-brake—and we had only four wheels out of eight wheels under the car fitted with our device.

The Boston & Albany R. R. are fitting up their coaches with our device; and the Big Four and hundreds of electric cars in the United States, Europe and Africa have been fitted during the past five years. On the Newton Circuit of the Boston & Albany R. R., the local trains make 22 stops in 21 miles in 1 hour and 2 minutes, and the average reduction of air with the old method of hanging the brakes was 15 to 18 lbs. for each stop. With our method it is from 6 to 8 lbs. and the engineer is absolutely sure of stopping at the platform without going into emergency or throwing all the passengers off their feet.

Thanking you, we remain,

John Hector Graham, M. E.,
For the Safety Appliance-Equipment Co.

561 Boylston St., Boston, Mass., Aug. 8, 1900.

Notes and Queries.

An item in the department of "Personals" in our issue of Aug. 9, stated that Mr. Edward P. North, Vice-President, Am. Soc. C. E., was in Berlin, engaged in an inquiry into the economic value of technically educated labor. Since its publication we learn that the Mr. Edward North who is in Berlin engaged in the above-named work is a member of the staff of the Department of Labor and not the well-known engineer.

DIAGRAM FOR DETERMINING THE VOLUME OF SEMI-ELLIPTICAL GROINED ARCH VAULTING.

By John H. Gregory, Jun. Am. Soc. C. E.*

The groined arch as a covering for reservoirs and filter beds has been coming into greater use in recent years in this country, and the engineer is often confronted with the problem of determining the volume of such a structure. Many forms of vaulting can be used, but that most commonly employed is the semi-elliptical. The mathematical work† of computing the volume of such a groined arch is not a very complicated matter, but it can be considerably simplified by the use of a diagram, and it is with this end in view that the writer submits the accompanying diagram. For quick use it will be found very convenient and sufficiently accurate for practical purposes, but should great accuracy be required the exact formulas, as given on the diagram, can be used.

The use of the diagram consists briefly in the finding of three volumes, m, n and p, and of a

*Assistant Engineer, Improvement of Water Supply, City Hall, Philadelphia.

†See Proc. Am. Soc. C. E., Vol. XXV., No. 5, for an excellent paper on "The Groined Arch as a Covering for Reservoirs and Sand Filters: Its Strength and Volume," by Leonard Metcalf, Assoc. M. Am. Soc. C. E.

short arithmetical computation. The meaning of the various letters is given on the diagram, but it may be a little clearer to describe what the volumes m, n and p represent.

The first, or m, is the volume over one pier included between the plane passing through the springing lines of the arches and the plane tangent to the intrados of the arches at the crown; n is the volume of the rectangular parallelopiped included between the planes tangent to the intrados and extrados at the crown; p is the volume of the depression, whose height is d, below the plane tangent to the extrados of the arches at the crown.

The limiting lines of all three volumes in plan are the center lines of the arches adjacent to one pier.

Having given a, b, c, d and t, the value of m, n and p are found as follows:

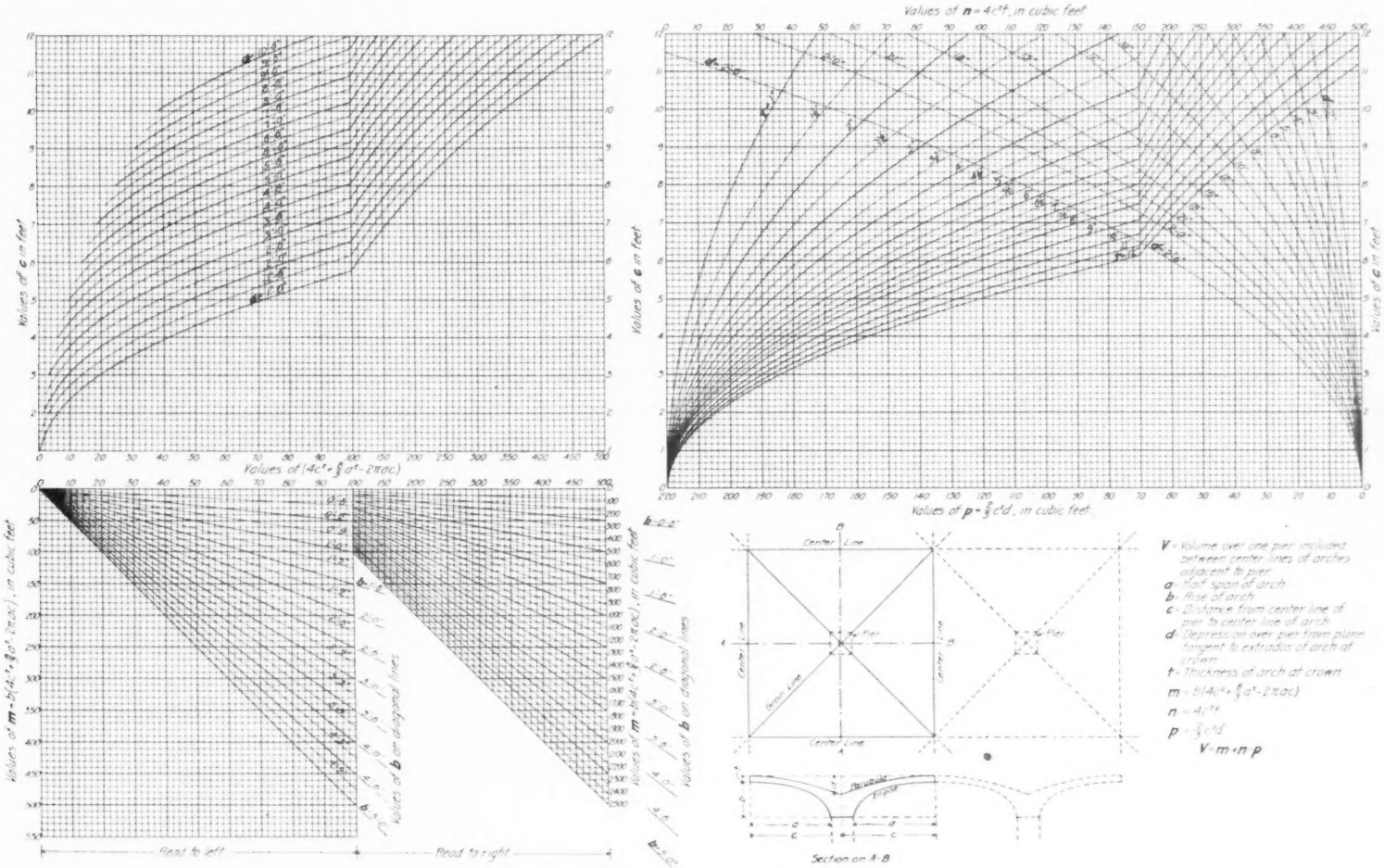

Values of n = 4c²t, in cubic feet
Values of c in feet
Values of (4c² + 8/3 a² - 2πac)
Values of m = b(4c² + 8/3 a² - 2πac), in cubic feet
Values of b on diagonal lines
Read to left
Read to right
Values of p = 8/3 c²d, in cubic feet
Center Line
Pier
Section on A-B
V = Volume over one pier included between center lines of arches adjacent to pier
a = Half span of arch
b = Rise of arch
c = Distance from center line of pier to center line of arch
d = Depression over pier from plane tangent to extrados of arch at crown
t = Thickness of arch at crown
m = b(4c² + 8/3 a² - 2πac)
n = 4c²t
p = 8/3 c²d
V = m + n + p

DIAGRAM FOR DETERMINING VOLUME OF SEMI-ELLIPTICAL GROINED ARCH VAULTING.
By John H. Gregory, Jun. Am. Soc. C. E.

For m, using the upper left hand diagram, find the intersection of the horizontal line, c, with the curved line, a; follow this down to the multiplication diagram below until it intersects the diagonal line, b, then reading to right or left the value of m is found.

For n, using the upper right hand diagram, find the intersection of the horizontal line, c, with the curved line, t, and reading up the value of n is found.

Similarly for p, on the same diagram, find the intersection of the same horizontal line, c, with the curved line, d, and reading down the value of p is found.

For example: If a = 6 ft. 10 ins., b = 2 ft. 9 ins., c = 7 ft. 9 ins., d = 18 ins., and t = 6 ins.,

$$m = +\ 88.5$$
$$n = +\ 119.8$$
$$m + n = +\ 208.3$$
$$p = -\ 60.0$$
$$V = +\ 148.3 \text{ cu. ft.}$$

By computation from the formula, V = 148.1 cu. ft.

If the vaulting is horizontal on top and has no depression, p becomes zero. The diagram is applicable to semicircular groined arches up to a span of 10 ft. by making b = a.

THE POSSIBILITIES OF ELECTRIC HEAT AS LIMITED BY THE COST OF PRODUCTION.

By Alton D. Adams.*

Electric heat is pleasing and very convenient for various small operations. There are some processes in which the value of the amount of heat energy consumed is trifling compared with the necessity for its delivery in a certain place at an exact time, and for these the electric product is eminently suited. There is current, however, an opinion that electric heat has a much wider legitimate field of application than that included in temporary and mechanical operations, and may at least play an important part in manufacturing processes that require large amounts of continuous heat now generally derived from coal. Even in statements concerning the limits of electric heat, these limits have often been assigned to the high cost of its necessary fuel, and confidence expressed that a large improvement in the combined efficiency of the apparatus between the coal pile and the dynamo will render the general application of electric heat practicable. Large water powers appeal to some as peculiarly suited to the cheap production of electric heat, and schemes for the promotion of such enterprises are not infrequently put before investors. Some months since a plan for the development of a water power in Nebraska, at a point where coal is high in price, this power to be largely used for electric heating, was earnestly and persistently brought to the writer's attention, and the promoter seemed somewhat aggrieved that it did not receive endorsement.

Now the facts as to the commercial possibilities of electric heating are that, not only is the cost of fuel or of water power for electric heat production many times that of coal for a given heating effect direct from combustion, but an attempt will here be made to show that the investment in machinery is so great for electric heat, that it is entirely impracticable for general use, even with free fuel or water power for its production.

Let us inquire first as to the fuel consumption necessary to produce electric heat from coal through the medium of boiler, engine and dynamo. The efficiency of boilers may be taken at 70% of steam engines at 12%, and of dynamos at 90%, thus giving a combined efficiency of $.70 \times .12 \times .90 = .0756$, which is the ratio of the electric energy delivered at dynamo terminals to the heat energy developed in the boiler furnace by the complete combustion of the coal. As the boilers are assumed above to have an efficiency of 70%, in the production of steam, which may all be applied to heating purposes, while the dynamo delivers but 7.5% of the coal's energy, the fuel consumed for electric heat is $70 \div 7.5 = 9.3$ times as much as that used to produce an equal amount of heat from steam.

Compute next the machinery necessary to supply electric heat, in place of an ordinary steam plant: Suppose a plant in which one ton of coal must be burned in the boiler furnace during ten hours to furnish the desired amount of direct steam heat. Let it be required to displace this steam heating system with a plant for the production of an equal amount of electric heat. Assuming that the 2,000 pounds of coal used for steam heat during ten hours contains 12,000 heat units per pound, and, as before, that the boilers have an efficiency of 70%, the electric heat delivered per hour must amount to $12{,}000\ (2{,}000 \div 10)\ .7 = 1{,}680{,}000$ heat units. One electrical or mechanical horse-power hour is the equivalent of 2,545 heat units, so that the dynamos must deliver energy at the rate of $1{,}680{,}000 \div 2{,}545 = 660$ electrical horse-power. With an efficiency of 90 per cent. for the dynamos the capacity of their driving engines is, therefore, $660 \div .9 = 733$, brake horse-power. The installed cost of dynamos and connections for the electric heating may be taken at $660 \times \$25 = \$16{,}500$, and for engines, boilers and connections $733 \times \$50 = \$36{,}650$; or a total for the electric power plant of $\$16{,}500 + \$36{,}650 = \$53{,}150$. The installed price of the boiler used to supply steam for direct heating and using one ton of coal during ten hours should not be more than $1,800, so that the excess of plant investment for the electric heat is $\$53{,}150 - \$1{,}800 = \$51{,}350$. Steam pipes and heaters for the distribution of direct steam heat may be fairly considered to cost about the same as electric wires and heaters of the same capacity.

*Box 1377, Boston, Mass.

Since coal for the electric heating plant is, as above shown, 9.3 times as much as that required where direct steam heat is used, this increase of fuel will be prohibitive in itself, with coal at any ordinary value, amounting to ($2 × 9.3) − $2 = $16.60 each ten hours of operation with coal at $2 per ton. Even with free coal the increased labor charge for handling would be a serious impediment to the adoption of electric heat. The skilled labor necessary to operate the necessary engines and dynamos would add another heavy expense to the electric plant.

Besides this excess in operating expenses, the plant for electric heat must support the fixed charges on the $51,350 above found, which at 16 per cent. for interest, depreciation and repairs, amount to $51,350 × .16 = $8,216, yearly, or on the basis of 300 working days, to $8,216 ÷ 300 = $27.39 per day. An increase in the combined efficiency of engines and boilers might reduce their cost for a plant of given capacity, but the output and investment for dynamos would even then remain constant, so that the total cost would still be a large part of the above-named sum.

It may be urged, however, that with cheap water power, electric heating might be made practicable. Without entering into the question of cost for water power development, the very low price of $12 per horse-power at the wheel shaft, for a working year of 3,000 hours may be assumed. This price corresponds to $12 ÷ 3,000 = $0.004 per hour, or $0.04 per 10-hour day for each horse-power. Reverting to the steam heating plant which requires 2,000 pounds of coal per 10-hour day, burned under boilers of 70% efficiency, and delivering 1,680,000 heat units per hour, the water power dynamos must furnish work, as did the steam engine and electric plant, at the rate of 1,680,000 ÷ 2,545 = 660 electrical horse-power, and the water wheel shaft at the rate of 660 ÷ 90 = 733 mechanical horse-power. The daily cost of the energy from water wheel shaft is, therefore, $0.04 × 733 = $29.42, as compared with about $3 to $4 for the price of a ton of fairly good coal to give the same amount of heat. Even at the low rate for water power above assumed, it costs as much for electric heat as coal would for steam heat at a price of $29.42 per ton. In order that the electric heat from water power should have an energy cost no higher than that of steam heat from coal at $3.00 per ton, the charge per horse-power year for the energy at the water wheel shaft cannot be more than ($3.00 ÷ 733) 300 = $1.20.

Again, to transform power from the wheel shaft to electric energy there must be provided dynamos for 660 electrical horse-power, which at $25 per horse-power capacity installed with connections amount, as above, to $16,500. Allowing again for the steam heating boiler a complete erected cost of $1,800, the excess of investment for the electric heat is $16,500 − $1,800 = $14,700 and at 16%, for fixed charges the extra outlay on the electric over the direct steam equipment for interest, depreciation and repairs, amounts to $14,700 × 16 = $2,352 yearly, or $2,352 ÷ 300 = $6.92 per day. The care of dynamos having 660 horse-power capacity will certainly require as much labor as that of a steam boiler that consumes one ton of coal in ten hours for heating. If, therefore, water power is developed and delivered to the dynamo shaft absolutely free of cost to the user, the fixed charges on the equipment for electric heat amount to more than does coal for steam heat at $6.92 per ton.

COMPARATIVE ESTIMATES OF THE COST OF COMBINATION AND ALL-STEEL HIGHWAY BRIDGES.

By H. G. Tyrrell.*

The bridge in question was a single span structure designed for the Pacific coast. The trusses were to be pin-connected with 10 panels of 19 ft. each, and inclined top chord. The principal dimensions and specified loads were as follows:

Span, 190 ft. c. to c.
Roadway, 24 ft.
Two walks, each 6 ft. wide.
Total width of bridge, 41 ft.
Depth of truss, 27 ft. to 33 ft.

*Asst. Engr. Boston Bridge Works, Boston, Mass.

Floor, 4-in. wood block paving on 3-in. plank, laid on wood joists.
Uniform live load on floor, 100 lbs. per sq. ft.
Concentrated load on floor, 15-ton roller or two electric cars on each track.
Live load, per lin. ft. of bridge, 3,300 lbs.
Dead load per lin. ft. of bridge, 2,345 lbs.

For the combination design hard pine was used for top chords, web-posts, portals, lateral struts, floor beams and joists. The remaining parts were of steel.

The estimated quantities for this case were:

Eye-bars	42,180 lbs.	
Cast-iron joint blocks	19,720 "	
Lateral rods	5,810 "	
Machined work	5,940 "	
Shoe plates	5,200 "	
Loops	3,160 "	
Hangers	1,240 "	
Total	83,250 "	Cost, $3,130
Hard pine chords and posts	17.50 ft. B.M.	
" " lateral struts	3.08 " "	
Floor plank	19.74 " "	
" joists	22.24 " "	
" beams	14.80 " "	
Total	77.36 " "	Cost, $2,400
Paving 504 sq yds	"	750
Fence, 400 lin. ft.	"	200
Erection	"	1,200
Total cost of combination span = about $1 per sq. ft. of total floor	"	$7,680

For the all-steel design the quantities were:

Steel, 180,000 lbs	Cost,	$7,360
Floor plank, 19.74 M. } Wood joist, 22.24 M. }	"	1,435
Fence, 400 lin. ft.	"	200
Paving, 504 sq. yds.	"	750
Erection	"	1,200
Total cost of steel span, about $1.43 per sq. ft. of total floor		$10,945

The above estimates are for the entire superstructure in each case. If we compare now the cost of the substituted parts only, we have in the combination design, the top chords, web posts, portals, lateral struts and floor beams contain:

Hard pine, 35.3 M @ $35 per M	$1,220
Cast-iron joint blocks, 19.70 lbs. @ 3 cts.	591
Total	$1,811

For the all-steel design the same parts contain:

Steel, 118,200 lbs., @ 4 cts.	$4,720

Summarizing, we have:

Combination bridge	Cost,	$7,680
Steel bridge	"	10,945
Combination chords, etc.	"	1,811
Steel chords, etc.	"	4,720

Hence, we may say roughly that the combination bridge cost one-third less than the steel one. Also that the comparative cost of wood (including necessary cast-iron blocks), and steel for top chords, web posts, portals, lateral struts and floor beams is as 1 to 3.

PARIS EXPOSITION AWARDS TO ENGINEERING EXHIBITORS.

The pleasing news is cabled from Paris and published in the "New York Times" of Aug. 18, that United States exhibitors at the Paris Exposition have received no less than 1,981 awards. Of these 220 are Grand Prizes, 486 are gold medals, 583 are silver medals, 422 are bronze medals, and 270 are honorable mentions. Our contemporary publishes a list of the grand prizes and gold medals awarded, and we reprint such parts of the list as relate to the awards in the departments of civil, mining and mechanical engineering, as follows:

Department of Machinery—Group IV.

Grand Prizes.

Worthington Pumping Engine Co.
Batcheller Pneumatic Tube Co.
Brown & Sharpe Manufacturing Co.
Pratt & Whitney Co.
E. W. Bliss Co.
Niles Tool Works Co.
J. A. Fay & Egan Co.

Gold Medals

Ball Engine Co.
William Sellers Co.
George F. Blake Mfg. Co.
Tinius Olsen & Co
Otis Elevator Co.
Rand Drill Co.
Charles A. Schieren & Co.
Crane Co.
Ingersoll-Sergeant Drill Co.
Shaw Electric Crane Co.
Simonds Manufacturing Co.
Chicago Pneumatic Tool Co.
Morse Twist Drill & Machine Co.
Cincinnati Milling Machine Co.
Hendy Machine Co.
Warner & Swasey.
Norton Emery Wheel Co.
Bement-Miles Co.
E. C. Atkins & Co.
Gisholt Machine Co.
Jones & Lamson Machine Co.
F. E. Reed Co.
Deering Harvester Co.
Bullard Tool Co.
Pond Machine Tool Co.

Department of Machinery—Group V.

Grand Prizes.

American Steel & Wire Co.
E. C. Acheson.
Rowland Telegraphic Co.
Western Electric Co.
John R. Roebling's Sons Co.

Gold Medals.

Bullock Electric Manufacturing Co.
Lorain Steel Co.
Western Electric Co.
Alvin Manufacturing Co.
National Carbon Co.
Tiffany Glass & Decorating Co.
C. J. Toerring Co.
Ward Leonard & Co.
Helios-Upton Co.
Holophane Glass Co.
Hart & Hegeman Manufacturing Co.
Edison Phonograph Co.
Western Electrical Instrument Co.
Mica Insulator Co.

Department of Civil Engineering and Transportation.

Mississippi River Commission.
George A. Fuller Co.
Lindon W. Bates.
City of New York.
Phoenix Bridge Co.
American Society of Civil Engineers.
Chicago Sanitary District (Drainage Canal).
Boston Transit Commission.
Boston Terminal Co.
Columbia Factory, American Bicycle Co.
United States Post Office Museum.
Baldwin Locomotive Works.
Pressed Steel Car Co.
J. G. Brill Co.
Westinghouse Air Brake Co.
C. A. Coolidge and M. Goustiaux.
Standard Electric Co. of California.
Corydon T. Purdy.
Kansas City & Memphis Ry. & Bridge Co.
Lewis A. Haupt.
City of San Francisco.
Barber Asphalt Paving Co.
State of Massachusetts.
Engineering News Publishing Co.
Baldwin Co.
Deering Harvester Co.
United States Express Co.
Metropolitan Park Board of Boston.
Metropolitan Sewerage Board of Boston.
Metropolitan Water Board of Boston.
Board of Park Commissioners of Boston.
Board of Street Commissioners of Boston.
Cleveland Factory (American Bicycle Co.).
Monarch Factory (American Bicycle Co.).
Crescent Factory (American Bicycle Co.).
Chain Factory (American Bicycle Co.).
American Steel & Wire Co.
American Electric Vehicle Co.
Columbus Buggy Co.
American Railway Master Mechanics' Association.
American Railway Association.
The Master Car Builders' Association.
Gould Coupler Co.
International Pneumatic Signal Co.
McConway & Torley Co.
The New York Air Brake Co.
New York Yacht Club.
Commissioner General of the United States.
International Navigation Co.
Seawanhaka Yacht Club.

Mining and Metallurgy—Group II.

American Steel & Wire Co.
California State Commission.
Colorado Fuel & Iron Co., Denver, Colo.
Copper Queen Consolidated Mining Co., New York city.
United States Geological Survey, Washington, D. C.
Ingersoll-Sergeant Drill Co., New York city.
Oil Well Supply Co., New York city.
American Museum of Natural History, New York city.
Lehigh Valley Coal Co., Wilkesbarre, Pa.
Department of Mining and Metallurgy, United States Commission to the Paris Exposition, F. J. V. Skiff, Director.
American Institute of Mining Engineers, New York city.
Barney Marble Co., Swanton, Vt.
Bullock, M. C., Manufacturing Co., Chicago.
California State Mining Bureau, San Francisco, Cal.
Brake & Co., St. Paul, Minn.
Jeffrey Manufacturing Co., Columbus, O.
George F. Kunz, New York.
New Almaden Quicksilver Mining Co., New Almaden, Cal.
New York State Museum.
North Carolina State Board of Agriculture, Raleigh, N. C.
North Carolina State Commission to the Paris Exposition, Raleigh, N. C.
Pike Manufacturing Co., Pike Station, N. H.
Rand Drill Co., New York city.
Robins Conveying Belt Co., Park Row Building, New York city.
Charles Kirchoff, New York city.
Richard P. Rothwell, New York.
Frank E. Saward, New York city.
M. H. Fuller, Massachusetts Institute of Technology, Boston.
American Steel & Wire Co., New York city.
American Tin Plate Co., New York city.
Crescent Steel Co., Pittsburg, Pa.
Iron Age Publishing Co., New York city.
Wellmann-Seaver Engineering Co., Cleveland, O.
Colorado Smelting & Mining Co., Denver, Colo.
John A. Roebling's Sons Co., Trenton, N. J.
Fayette R. Plumb, Frankford, Philadelphia, Pa.
The Hibbard-Rodman-Ely Co., New York.
The Eagle Lock Co., Terryville, Conn.
Yale & Towne Manufacturing Co., New York city.
Winslow Brothers' Co., Chicago.

Simonds Manufacturing Co., Fitchburg, Mass.
J. & H. Williams Co., Brooklyn.
E C. Atkins & Co., Indianapolis.
Bommer Brothers, Brooklyn, N. Y.
The Stanley Works, New Britain, Conn.

MACHINE SNOW PLOWS ON THE COLORADO MIDLAND RY.

Railways in regions subject to heavy snow usually have more or less difficulty in keeping the lines open during the winter, and this is especially the case in the mountains, where the snow accumulates sometimes to an extraordinary depth. The introduction of the machine snow plows or snow excavators has rendered the work of keeping the lines open and of opening blockaded lines very much easier than when bucking plows and hand shovelling were the only means available, but there are limits to the use of these excavators.

The Colorado Midland Ry. has had considerable and unpleasant experience in dealing with snow, and has tried the two forms of snow excavators in use in this country, with results which are noted below. On this line the snow is sometimes 30 ft. deep, and there are grades of 3% with sharp curves on the part of the line where the greatest trouble is experienced from heavy snow. The two forms of snow plows noted above are the Leslie and the Jull. The former has a vertical wheel set across the track, having radial knives which shear off the face of the snow, the material thus removed falling back behind the knives and being thrown out through a spout by the centrifugal force of the wheel. The latter plow has a huge horizontal cone set diagonally to the track, with a spiral cutting blade riveted upon it, the cone boring its way into the snow, and delivering it through a spout by the centrifugal force developed at the rear of the cone. The wheel or cone is revolved at high speed by the machinery on the plow, and the whole machine is pushed forward by several locomotives. The latest machine on the Colorado Midland Ry. is of the Leslie type, commonly known as the "rotary" plow, and was built in 1899 by the Rotary Snow Plow Co., of Paterson, N. J., at the Cooke Locomotive Works. Its engine has cylinders 18×26 ins., with the Walschaert valve gear, and the boiler is of the Belpaire type, 67 ins. diameter in the barrel, carrying a pressure of 190 lbs. The machine resembles a large wrecking car, with four 12-in. I-beams for sills, and having a circular shell or drum at the front end, in which is the wheel, 11 ft. 6 ins. diameter. At the front of the drum is a rectangular hood, trimming the sides and bottom of the cut. This is 12 ft. wide, leaving only 3 ins. of dead surface on each side of the wheel to be sheared off by the hood. The wheel has 12 radial, conical tubes, with a slot in the face of each, fitted with a blade 4 ft. 6 ins. long, the snow falling through the tubes into the back of the wheel, which acts as a powerful discharge fan. The machine has ice cutters capable of cutting ice 2 to 3 ins. thick on the rails, and has also flanges which remove the snow and ice between the rails and deliver it outside the track. The machine weighs about 170,000 lbs., and has a tender carrying 4,000 gallons of water and 11 tons of coal.

As a result of the experience with the two kinds of plows, the preference is for the rotary machine. Either the Leslie "rotary" or the Jull "cyclone" plow will cut its way through newly fallen snow drifts ranging from 3 ft. to 6 ft. deep at a rate of from eight to ten miles an hour, and through snow not exceeding 10 to 11 ft. deep at a rate of from five to six miles an hour. Experience has shown that the rotary plow delivers the snow in a clean stream from the outlet over the wheel, and by reason of the velocity with which it discharges the snow throws it to a distance of 40 ft. to 200 ft. from the track. The distance varies with the velocity of the wheel. On the other hand, it was found that with the "cyclone" plow, the snow was thrown in promiscuous ways, some going to the right of the plow, some to the left, and some falling directly on top of the machine. This method of delivery is much less effective on a mountain road. It must be considered, however, that the two Jull cyclone plows which were in use on this line during the severe winter of 1898-99 were old ones, rented for the season. Both were formerly used on prairie roads, and their flangers and ice cutters were not constructed for work on a mountain road, causing serious trouble and delays as the result of frequent derailments.

In the very hard snow encountered during the winter of 1898-99, it was impossible to advance 1,000 ft. in the snow in an hour, even after channels 4 to 6 ft. long at right angles with the track had been dug from the surface down to the rails, leaving from 7 to 10 ft. of snow between the channels. This was the case even when the rotary plow was handled with five engines. The object in using so many engines was to push the plow into the snow so as barely to move the plow, and, at the same time, keep it moving all the time and so prevent stalling the train or choking the plow. The snow was channeled so that there might be in front of the plow, at one time, no more snow than could be moved without danger of crushing the plow, as might be done by putting the front of the plow against a solid wall and pushing against it with five powerful engines. The result of forcing the plow into unchanneled snow was practically the same as forcing it against a wall of rock.

In some places the plow encountered snow 34 ft. deep. At such points it was clearly impossible for the plow to act effectively, because even if it had been possible to push the plow into such a depth of snow it could only tunnel into the snow a few feet before the outlet over the wheel would be closed by the overhanging body of snow, and it would be impossible for the wheel to throw the snow away. Under such circumstances, the only practicable method was to place lines of men above each other on the slopes of the cut, one line of men throwing the snow up to the one immediately above, they in turn to cast the snow above them, and so on until it was raised to a height varying from 40 to 60 ft., and finally disposed of, leaving not more than 12 ft. of snow in the bottom of the cut. Holes were drilled into this bench of snow and giant powder exploded to shatter the frozen bank, after which the men were stationed on the bench of snow immediately in front of the plow to drag the snow down with shovels and throw it in the bottom of the cut in chunks from 1 cu. ft. to 2 cu. yds. in size. After breaking this snow down, the plow would run into the loose snow, throw it up on the bench excavated on the slope of the cut for the men to stand on, and the men would shovel it one to the other again until it could be disposed of over the top of the cut. Each time the plow would run into the shattered snow it would remove that snow and force itself from 5 to 10 ft. into the undisturbed mass of snow. Progress was necessarily exceedingly slow in such work. The Jull plows were of but little service in this class of work, as the manner in which the snow was delivered from the wheel caused the snow to fall back around the plow, settling between it and the perpendicular walls of snow between which it would be working, and sealing the plow into the cut almost as firmly as if it had been run into solid rock. The rotary, on the contrary, would deliver a clean stream of snow, nearly as large as a flour barrel, very much as a stream of water is delivered from a fire hose. As long as the wheel could be turned at its highest velocity the snow would be delivered so far up on the sides of the cut that very little of it would roll down around the plow. The experience was that the Jull plow took much more power to force it into deep and hard snow, and great difficulty was experienced by reason of this plow becoming derailed.

It was found almost impossible successfully to operate a plow unless equipped with very strong and substantial ice cutters in front of the forward trucks, so as to remove any ice which might have formed on the rail, and as it is very necessary to remove entirely the snow and ice from the rails in order to give the engines a good grip on the rails, it is necessary to have the plow as close to the rail as possible. One of the plows stood 4 to 5 ins. above the rail. This left so much snow on top of the rail for the flanger to move that it would be thrown up against the banks, and as soon as the flanger had passed it would roll back on to the rails, leaving a very bad rail, often covered by 6 to 8 ins. of snow. This would cause the engines to slip badly, and ice would form to such an extent that often the plow train could not proceed more than a train length without stopping while the track was flanged by hand, so as to give the engines a footing and enable them to do the work. Another difficulty experienced was with the hood springing and giving way, but in the new machine this has been provided against by using a larger wheel, cutting to within 3 ins. of the side of the hood.

PROF. PUPIN'S PROPOSED SYSTEM FOR LONG-DISTANCE TELEPHONING.

By H. T. Wade.*

The extension of the limits of long distance telephoning and the increase in the rate of speed in the operation of ocean cables are two problems in practical electricity which have waited many years for their solution. Telephoning as now practised over long distance lines has been made possible by refinements in the construction of the apparatus and the use of heavy conductors of low resistance rather than by the application of any new principles or original ideas. Likewise in the case of the ocean cable, now used for a half century, there has been but little increase in the rate at which it could be operated, save by the manufacture of larger and correspondingly more expensive conductors. In the course of an elaborate series of experiments on long electrical waves, Prof. M. I. Pupin, of the Department of Mechanics at Columbia University, has ascertained that it is possible to construct conductors which will greatly increase the distances over which the telephone can be used, make its employment on submarine lines possible, and which will also make possible an increase of the speed at which telegraph messages are transmitted on cables. These propositions have been experimentally demonstrated; the theory on which they are based has been verified, and now the practical development of the system is being undertaken.

Before discussing the way in which these results are attained or the theoretical considerations involved, it may possibly be well to consider the conditions to be encountered in this branch of electrical work. It is a case of the transmission of electrical energy over a conductor for a long distance, and as the transmission is not constant, but consists of a series of impulses, it takes the form of electrical waves. The distance is so great that we have to take into consideration the reactions set up in the conductor over which the energy is transmitted as well as the reactions in the receiving instrument. If the supply of energy is constant or occurs at intervals of not too great frequency, there is no serious difficulty to be noted, but when we have rapid impulses, as in the case of the current over a telephone conductor or the current from mechanical telegraph instruments, the effect of the conductor on the waves becomes an extremely important matter. The electrical energy to be transmitted is stored up in the medium surrounding the transmission line, and then communicated to the receiving apparatus. This energy is distributed periodically over the line, and we have what is known as an electrical wave. Taking two points at which we have similar conditions of current or potential we can consider the distance between them as a half wave length; and if we multiply the distance by two and then by the frequency of oscillation, we have the velocity of propagation. The velocity of electrical waves varies greatly, from the velocity of light down to comparatively low values. This velocity depends upon properties of the line known as inductance, resistance and capacity. Were the wire a perfect conductor, we would have energy transmitted over it without loss, but on account of its resistance or imperfect conductivity a dissipation occurs, which, however, may be regulated by the inductance and capacity. By inductance we mean the force opposing the increase or decrease of a current, and which is due to the magnetic field set up by that current. By capacity is meant the property of storing up electricity which is possessed by a conductor. Consequently, if there is a proper amount of inductance and ca-

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pacity in the circuit, the electrical energy may be stored up in the surrounding medium in the forms of magnetic energy and electrostatic energy. From a mathematical consideration of the subject it may be seen that an increase in the inductance of a wire increases the efficiency of transmission. This fact was known by earlier investigators, but the construction of a satisfactory long distance conductor containing inductance has never been successfully accomplished until a proper theory was developed by Professor Pupin. In previous experiments inductance coils introduced either at periodically recurring distances or at arbitrary intervals, were found of no avail, and instead of assisting in the transmission of the waves often served to reflect and distort them. It was discovered by Professor Pupin that the inductance must be added at carefully determined points, and when this is done a conductor is secured which acts like a uniform conductor and transmits the electrical energy with the smallest possible dissipation. An analogy is to be found in the case of a vibrating cord which can be loaded in such a way as to vibrate in a manner similar to a heavier cord of uniform section. In fact the mathematical law governing the vibration of a cord under such conditions is precisely the same, and the analogy may be used in the interest of lucidity, as the vibrations of a string can be understood more readily than the changes involved in the case of electrical waves. Suppose a cord fastened at one end and vibrating with a certain periodicity. The waves as they strike against the surface where it is fastened are reflected and stationary waves are produced in the cord, that is, if the frictional resistances are sufficiently small. If not, the incident and reflected waves will not be equal and the waves nearest the reflecting surface will vibrate with less amplitude than those at the source of motion. Now, a heavier cord will transmit the energy far better, though of course the waves will have less amplitude, as an increase of mass diminishes the velocity, and a diminished velocity means smaller losses from friction. This increase in the density of the cord shortens the wave length, but it is a far more efficient means of transmitting energy. Such being the case, how is it possible to secure this result without the employment of a cord of great density? Naturally by loading the cord. A single weight at the middle point fails to improve the situation, and, as it becomes a source of reflection, far less energy is transmitted to the extremity of the string than before. Subdividing the weight brings little improvement until a point is reached where the weight is so distributed in small masses at regular intervals along the cord, that it vibrates very nearly like a uniform cord of the same mass, tension and frictional resistance.

Returning to the electrical conductor, from this analogy it is found theoretically and experimentally that the addition of inductance has the same effect as the addition of the weights to the vibrating cord, but that both must be placed at certain regular positions determined by calculation. Just as the cord when properly loaded vibrated as a uniform cord of equivalent mass, so a non-uniform conductor can become practically equivalent to a uniform conductor if the conditions of the theory are fulfilled. Making the distance between any two inductance points such that it shall bear the same relation to the wave length as the angular distance on the sine curve of current between these points does to the circumference, it is found that the non-uniform conductor is as nearly equivalent to the uniform conductor as the sine of half the angular distance is to half the angular distance. The smaller the wave length, the smaller will be the distance between the points of inductance.

It is found that if the conductor acts with sufficient accuracy for waves of the shortest length, that is, for those of the highest frequency, it will serve satisfactorily for the longer waves. The practical application of this will be seen in telephony where the currents produced by the motion of the diaphragm have complex frequencies owing to the overtones or higher notes being mixed with the fundamental tones. Now, if the conductor is adjusted for a frequency of 1,000 vibrations per second, the greatest frequency which is considered in modern telephone practice, then the lower notes are taken care of satisfactorily and there is no distortion of speech.

From matters of theory to a concrete example is the next step. Suppose an ordinary twin telephone conductor, such as is usually employed, to have a length of 250 miles. The limiting distances over which telephoning is possible with such a cable are 39 and 78 miles, the former figure representing the limit set by the standard of the Metropolitan service in New York city, while the latter is the limit in long distance work. One mile of such a cable would have a resistance of 9 ohms and a capacity of .074 microfarads, and naturally very little inductance. If we add .056 henry of inductance at each mile there will be transmitted to the receiving instruments 2% of the current sent from the transmitting apparatus. Assuming for this purpose that 750 cycles per second will be the highest frequency to be used and a wave length of 14.6 miles, if an inductance coil with .056 henry of inductance and 9 ohms of resistance is added, there will be an agreement to within 1% between such a conductor and a corresponding uniform conductor. In a submarine cable the capacity is about four times as large as in the cable assumed. Consequently the inductance will have to be much larger. This will cut down the wave length and make it necessary to place the coils of inductance much nearer to each other,

The demonstration of the theory and the proof of the correctness of the reasoning were effected in the laboratory in a series of experiments carried out during a number of years. The apparatus required much thought in its preparation, as it was intended to reproduce in the laboratory the conditions of actual practice. The first important item was the cable, which was made in 250 sections, each section corresponding to a mile of ordinary cable. Each section consisted of a condenser made of paraffined paper, with a strip of tinfoil on each side. The tinfoil was in the form of a narrow strip, carried to and fro on the paraffined surface so as to secure the desired amount of resistance, which was 9.5 ohms, while the capacity was approximately .074 microfarads These conductors were grouped together in sets of fifty, but the wires from each section were led to brass plates, and any or all could be connected in the circuit at will. The coils of inductance, as demanded by the theory, are placed at intervals of one mile, and at the gaps between the sections of the cables the terminals of the coils were connected to brass plates so that they could be included in the circuit by merely removing the plug which served to short circuit them. The coils were wound so as to have an effective inductance of .058 henry each, and as in the case of the cable any or all could be added. The apparatus is arranged with the plugs inserted accurately resembling a uniform cable, while the removal of the plugs gives a non-uniform conductor 250 miles in length with inductance coils at intervals of one mile. With such a cable the wave length and the amount of attenuation of a current of given frequency could be studied and the effect of the inductance ascertained. To do this, it was necessary to impress upon the circuit a simple harmonic electromotive force, which was done by eliminating the upper harmonics or more rapid vibrations from the electromotive force given by an alternator. There being a simple alternating current in the circuit, which could be measured readily, it was possible to ascertain the positions of maximum potential and current from which a curve of the electromotive force could be plotted and the wave length computed. Various frequencies were used in the experiments and a close agreement between the calculated and observed wave lengths was obtained. The next experiments were undertaken to demonstrate the amount of attenuation or weakening of the current and here again the theory and experimental proof were found to agree closely, it being ascertained that the non-uniform conductor was equivalent to the corresponding uniform conductor. Changes in the amount or position of the inductance served to increase the attenuation, and also to occasion internal reflections which, particularly in telephony, are most injurious.

The experiments demonstrated conclusively that the proper addition of inductance in a circuit where there was a periodic electromotive force acted most beneficially and enabled the current to flow with far smaller losses of energy.

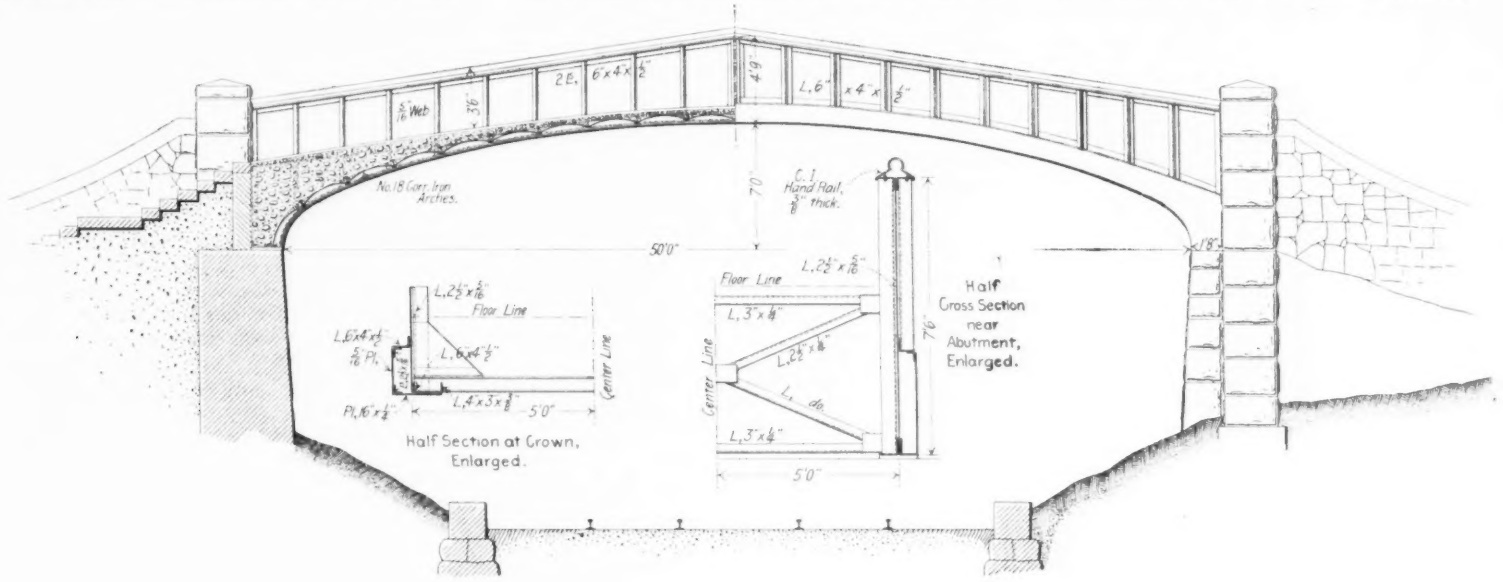
As the apparatus was designed to simulate a telephone cable, it was but natural that the first tests looking to a practical application of the system should be in telephoning. In no branch of telephony are its limitations more marked than when it is necessary to employ a cable, and the outcome of the experiments with the artificial cable and the inductance coils was awaited with much interest. It was found possible to talk through the entire length of 250 miles with the ordinary long distance transmitters and receivers. Now in actual practice something like 40 miles would be the limit of conversation, and if the cable were used without the inductance coils, conversation could be carried on only up to 50 miles with distinctness. Using the cable beyond this distance the articulation was rapidly lost, until at distances over 100 miles it practically disappeared. The experiments demonstrate the feasibility of submarine telephony across bodies of water far in excess of the present narrow limits, and indicate from a theoretical point of view the possibility of transatlantic telephony. The inductance coils could be attached to the cable at but slight expense, and enclosed within the sheathing without occasioning any difficulty in the manufacture or laying. It must not be understood that this system is only for cable telephony. Long distance telephony has been accomplished only by the use of copper conductors of large diameter and correspondingly large conductivity, which are extremely expensive. Even with these there are limits set on the distance, and lines between New Orleans or San Francisco and New York are still matters of the future. By the use of inductance coils placed on the cross bars of the poles in a manner similar to insulators, not only would the efficiency of the line be raised so as to greatly increase the present limits of long distance telephony, but the heavy copper conductors could be supplanted by others less expensive.

In ocean telegraphy the problem of rapid transmission of messages has been one of long standing, dating back to the establishment of the first Atlantic cable. When a certain rate of speed is exceeded the current becomes rapidly attenuated and the signal sent at the transmitting end of the line fails to affect the receiving instruments. This is due to the capacity of the cable, but by suitably regulating the inductance of the circuit the attenuation can be diminished and a rapid rate of transmission attained. From an economic standpoint this means a great deal, as a cable is an enormously expensive affair, and if its rate of operation is limited to an average rate of 30 words per minute, or at best 40 words, the tolls must be correspondingly high. The use of properly-arranged inductance coils would doubtless lead to important developments in cable practice, and the results of further experiments in this field are awaited with interest. A successful outcome is indicated from recent tests with a new chemical system of receiving telegrams, in which the messages are sent at high speed and are received on prepared paper where the action of the current causes a record to be made. The originator of this method, desiring to make a test of his instruments under extraordinary conditions, used Dr. Pupin's artificial cable as his line, and was able to transmit signals at the highest rate his instruments were capable of. Further tests in actual practice are to be made of the new form of conductors, and the reports will prove most interesting if all the conditions encountered in the laboratory experiments are realized.

PLATE GIRDER PARK FOOT-BRIDGE AT MADISON, N. J.

We illustrate in the accompanying engravings a foot bridge of simple and quite pleasing design, built during 1898 at Madison, N. J. This structure consists of two parallel arched, plate girders carried by masonry abutments which also form

the stairway approaches. The girders have a span of 50 ft. and are placed 10 ft. apart c. to c. Fig. 1 shows a part longitudinal section and part side elevation and also transverse sections near the abutment, and at an intermediate point between the abutment and crown. It will be noticed that the outside of each girder is provided with a projecting fascia on its lower part, varying in depth from 9 ins. at the crown to 3 ft. at the abutments. This fascia gives the bridge the appearance of a thin arch carrying a solid plate railing. Besides the transverse bracing indicated by the two transverse sections there is a lateral X-bracing below the floor beams. The floor is formed by corrugated iron arches sprung between the floor beams and filled above with concrete which carries the footwalk paving. Fig. 2 is a general view of the completed structure and it shows quite well the manner in which the metal structure harmonizes with the masonry abutment approaches. The bridge contains 27,500 lbs. of steel and 550 sq. ft. of corrugated iron. It was designed by Mr. H. G. Tyrrell, Assistant Engineer, Boston Bridge Works, Boston, Mass., to whom we are indebted for the matter from which this description has been prepared.



Half Longitudinal Section. Half Side Elevation.

FIG. 1.—ELEVATION AND SECTIONS OF ARCHED PLATE-GIRDER FOOT-BRIDGE AT MADISON, N. J.

REPORT OF THE MERCHANTS' ASSOCIATION ON THE WATER SUPPLY OF GREATER NEW YORK.

Following the agitation caused about a year ago by the proposed contract between the city of New York and the Ramapo Water Co., the Merchants' Association of New York formed a committee to investigate the whole subject of the present and future water supply of the city. This committee was divided into sub-committees on (1) Engineering, (2) Municipal Finance and Public Policy, (3) Legislation, and (4) Fire Protection and Insurance. The report on the investigation, which has just been published, makes a volume of nearly 700 pages, of which 400 are devoted to the report of the engineering committee, the latter also being accompanied with numerous maps and diagrams.

The committee on water supply, as the whole committee of 21 was entitled, was composed of men eminent for their business or professional attainments, with Mr. M. E. Bannin, of 83 Worth St., as chairman. Mr. S. C. Mead was detailed from the office staff of the Merchants' Association to serve as secretary to the committee, and Mr. F. B. De Berard acted as assistant to the chairman and secretary to the sub-committee on engineering. The names of the members of the engineering committee are given further on. Of the other committees, Mr. Horace E. Deming was chairman of the one on municipal finance and public policy; Mr. Arthur J. Baldwin was chairman of the one on legislation; and Mr. John R. Van Wormer was chairman of the one on fire protection and insurance. The report of each of the sub-committees contains much interesting and valuable matter, but we are compelled to confine our abstract chiefly to the report of the engineering committee, for reasons which will be readily appreciated when it is seen how much space it occupies.

Report of the General Committee.

The committee states that from Jan. 1, 1832, to Dec. 31, 1898, the city of New York (Manhattan and the Bronx) made a capital investment of $86,359,562 for the Croton, Bronx and Byram supplies, including the distributing systems; and that during the same period interest charges, maintenance and operation, aggregated $66,544,245. For these 67 years, the gross earnings were $88,017,330, leaving net profits of $21,473,084. The approximate average cost of water (Manhattan and the Bronx) in 1898, delivered to consumers, was $29 per 1,000,000 gallons. The price under the proposed Ramapo contract was $70, delivered at the city limits, to which $10 should be added for distribution, making $80 per 1,000,000 by contract, against $29, actual cost to the city in 1898. The committee then presents figures which show that the increased cost of water under the Ramapo contract, and the decrease in net revenue, as compared with an additional supply developed by the city, and entirely clear from debt, would, by the end of the Ramapo contract, leave New York $195,000,000 to the bad. While it might be easy for the other side to pick flaws in the methods employed to reach this grand total, it would be hard, indeed, to prove that the committee has erred except in degree; in other words, the committee and its sub-committees, have demonstrated that the Ramapo contract would have been a financial and engineering absurdity. The specific objections to the Ramapo contract are summarized by the committee as follows:

(1) The price is exorbitant.
(2) The contract is ambiguous as to the pressure at which the water is delivered at the city limits.
(3) The contract is ambiguous as to the respective duties and privileges of both contracting parties.
(4) The city will not own the plant at the termination of the contract.
(5) The effect of the contract will be to force the city hereafter always to purchase water from that company.
(6) It will deprive the city of large profits from a water supply owned by the city, or force it to raise the price of water, which would be injurious to its industrial interests.

Moreover, the experience of other municipalities in the United States, as well as in other countries, shows an almost continuous tendency to substitute publicly owned water systems for private, a tendency so persistent and so universal, and of such constantly increasing force, that the wisdom, in the public interest, of the policy of municipal ownership and control of water supply, would seem established by abundant experience.

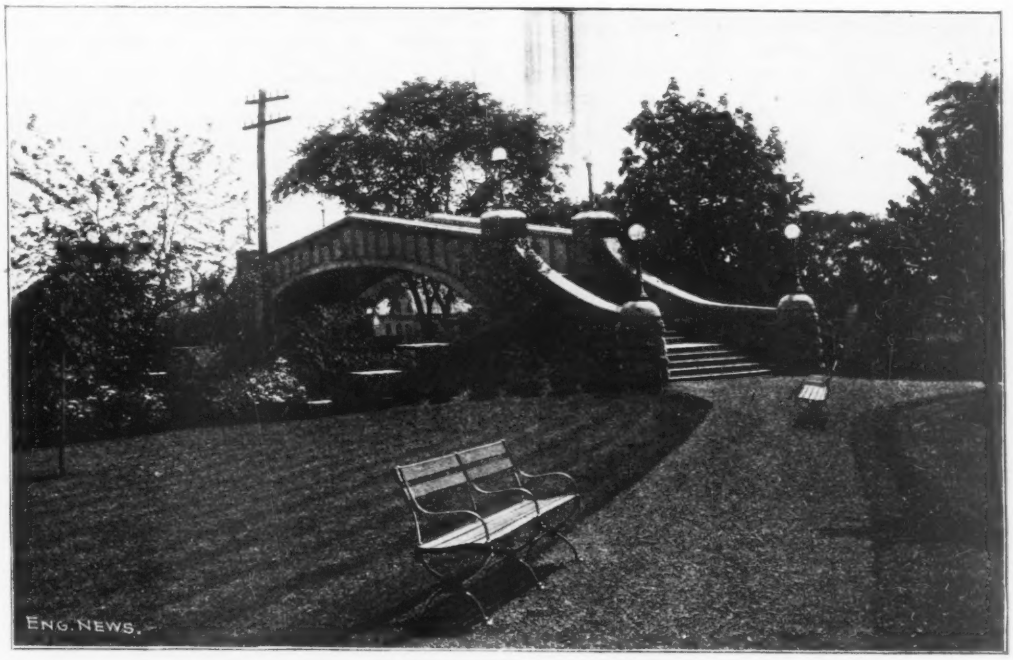


FIG. 2.—GENERAL VIEW OF ARCHED PLATE-GIRDER FOOT-BRIDGE AT MADISON, N. J.
H. G. Tyrrell, Assistant Engineer, Boston Bridge Works, Designer.

The other points of most interest to our readers are brought out in the report of the engineering committee, but before taking up that report the final recommendations of the committee on

water supply, which included all the sub-committees, may be given as follows:

I. No contract whatever should be entered into with the Ramapo Water Co.
II. The policy of supplying New York city with water by contract should be opposed by all lawful means.
III. The Legislature should clothe New York city with power to acquire by condemnation any water rights needed for its public water supply, excepting water rights actually used by, or necessary for, the supply of any other city, town or village.
IV. The constitutional requirement that the bonds issued by New York city for a water supply should be included in ascertaining whether the city can become indebted for other municipal purposes should be removed.
V. The Comptroller's quarterly and annual reports should contain a clear and business-like statement of the financial status of the city's investment in its water-works.
VI. A carefully devised system of detailed, accurate and easily understood public records and reports should be adopted by the Department of Water Supply.
VII. The financing by the city of any addition to its water supply should include the application of the surplus of the revenues over expenditures to the redemption of bonds issued to establish the plant.
VIII. Immediate steps should be taken by the city of New York to acquire an additional supply of 250,000,000 gallons of water daily from the Adirondack Mountain watershed by either of the systems proposed in this report.
IX. Immediate steps should be taken by the city officials to prevent the waste of water.

Report of the Engineering Committee.

The sub-committee on engineering was organized on Dec. 4, 1899, and submitted its report on June 15, 1900, or after continuing its labors for over six months. This committee was composed of ten members, as follows: Messrs. T. C. Clarke, R. Hering, E. P. North, H. S. Haines, D. McN. Stauffer, H. G. Prout, E. E. Olcott, H. R. Towne, D. Le Roy Dresser and R. R. Bowker. All the members except Mr. Bowker are engineers, and all the engineers save Messrs. Towne and Dresser are members of the American Society of Civil Engineers, while Mr. Towne is a member of the American Society of Mechanical Engineers.

The engineering committee was requested to investigate the present and future water supply of Greater New York, including the amount now used and likely to be required hereafter, and the available sources for an additional supply. To carry on its labors to the best advantage, the committee was authorized by the Merchants' Association to retain a number of eminent engineers, and the latter were empowered to engage engineering and clerical staffs. The various engineers retained and the subjects of their respective reports were as follows: Mr. J. J. R. Croes, M. Am. Soc. C. E., "The History, Condition and Needs of the New York City Water Supply and Restriction of Waste of Water." Mr, Lebbeus Ward, M. Am. Soc. C. E., "The Pumping Stations Connected with the Water Supply of New York;" Mr. Foster Crowell, M. Am. Soc. C. E., "The Use and Waste of Water in New York City," and "An Auxiliary Salt-Water Supply for Fire Protection, Street Washing, Sewer Cleansing and Other Purposes;" Mr. Jas. H. Fuertes, M. Am. Soc. C. E., "The Sources of Water Supply Suitable for the Future Use of the City of New York;" Mr. Geo. W. Rafter, M. Am. Soc. C. E., "A Water Supply from the Adirondack Mountains for the City of New York." Mr. Wm. B. Fuller, M. Am. Soc. C. E., made some special studies on the range of influence of salt water up the Hudson River and on the value of the New York water-works. Besides the reports of these engineers, the engineering committee had access to the manuscript of the report by Mr. Jas. R. Freeman, M. Am. Soc. C. E., on the same general subject, recently submitted to Mr. Bird S. Coler, Comptroller of New York city (see abstract, Engineering News, April 19, 1900); and to the reports made to the city of Brooklyn in 1896, on possible new sources of supply by the late W. E. Worthen and by Mr. I. M. De Varona, M. Am. Soc. C. E.

Present Water Supply and Waste.—Under this head the engineering committee present the following conclusions:

I. That the average daily consumption of water in all the boroughs of New York city in 1899 was 371,778,000 gallons, or an average daily consumption per capita of 103 gallons, which approximates to the lowest rate of consumption in any large American city.

II. That while the amount of waste is considerable, we do not see any present prospect that it will be materially reduced.

III. That an increased water supply will become a necessity within ten years or less, and examinations and surveys should be commenced immediately.

IV. That a reduction of waste by the extension of the meter system can and should be effected.

V. That more exact means should be provided for measuring and recording the actual consumption of water in all the boroughs.

VI. That the flow through the new Croton aqueduct should be increased by giving it a thorough cleaning.

VII. That a better distribution should immediately be effected in the Bronx.

VIII. That the present supply from the Croton should be increased, by urging the completion of Cornell reservoir, by the use of flashboards on the dams whereby a large additional amount of water may be secured, and also by the construction of new reservoirs, if found economical.

IX. That the present supply of Brooklyn should be increased and improved by building a 48-in. conduit from Millburn to Spring Creek to utilize the water now available; by the erection of additional pumps at Millburn; by filtering the water at Jameco and Springfield; by remodeling the high service at Mt. Prospect; and by making some of the other extensions and repairs now planned by the water department.

X. That the pollution of the surface waters of the Croton, Bronx and Long Island supplies is such as to warrant a purification of these waters by filtration as soon as this can reasonably be accomplished, this opinion having also been expressed by the Board of Health.

XI. That additional pumping machinery should be provided for the high service in Manhattan, and where required in other boroughs.

XII. That if 10% of the waste within buildings in all the boroughs can be saved by metering (this saving amounting to about ten gallons daily per capita of the population of 3,608,000) this saving, together with the available increase of supply, referred to above, would probably enable the city to tide over a period not exceeding ten years, which would barely suffice to make new sources of water supply available.

A valuable summary of the main facts relating to the water supply of New York is given in Table I.

Of the 371,778,000 gallons of water supplied to the whole city daily in 1899, there was 23,399,000 gallons, or 6.3%, furnished by private companies, all of the latter being pumped. Of the 348,379,000 gallons per day furnished by the city, 248,500,000 was delivered by gravity, but 44,000,000 gallons of it was subsequently pumped to consumers.

From the estimates of Messrs. Croes, Freeman and Ward, the present daily consumption of water in the boroughs of Manhattan and Bronx is placed at about 245,000,000 gallons, with an average yearly increase of 15,000,000 gallons. This territory is supplied from the Croton and the Bronx and Byram, the maximum capacity of which, with flashboards on all dams, is placed at 265,000,000 gallons a day until the Cornell dam is finished and 290,000,000 gallons thereafter. With average rainfalls, and no reduction in per capita consumption, the supply would be in excess of the demand until 1903 was passed. The other boroughs are already near or have reached the danger limit; but, as stated in the foregoing summary, it is believed that the various measures therein recommended will tide over the supply for the whole city for perhaps ten years, or at least until an additional supply can be developed. The measures in question fall into two classes: (1) Developing the existing sources to their fullest capacity; and (2) restricting waste. Nothing further need be said on (1), it being pretty well covered in the summary. Regarding (2) it is worth while to note the grounds on which the engineering committee bases its belief that the reduction of waste can postpone the need for more water only a few years at best, particularly as the engineers who studied this phase of the subject for the committee, as well as Mr. Freeman, in the report on his independent investigation, all agree that the waste of water in New York is enormous.

The committee prefaces its remarks on the reduction of waste by the following statement:

> Fortunately, too, it is not merely a temporary expedient, but will be a means of economy and security for the future. Modern hydraulic engineers and water-works managers are agreed that it is quite within the resources of engineering and administration, at least in some cities, to save a considerable part of this waste. The most serious difficulties in the way are a mistaken public opinion and a fear of the political effect of an attempt to control the domestic use of water.

A little further along the committee says:

> In reviewing the whole subject we are inclined to share the view taken by Mr. Freeman to the extent that in this city great practical results in reducing the wastes are not promising, and that "it is dangerous to the public interests to be too hopeful about preventing waste when estimating the date when the new supply must be available, or in estimating its necessary magnitude, for with these hopes unfulfilled and the reservoirs emptied, the disaster would then be beyond remedy."

After stating that the reports of Messrs. Croes and Crowell contain valuable information relating to waste, but do not agree as to the amount of it

TABLE I.—SUMMARY OF STATISTICS RELATING TO THE PRESENT WATER SUPPLY OF GREATER NEW YORK.

Borough	Population 1899 (1)	Ownership	Source of water	Daily consumption, gallons (2) Gravity	Pumped	Total	Reservoir or direct pressure	Elev. Ft.*	Area in Acres (2) Supplied	Unsupplied	Total	Highest land supplied	Number of Taps	Average daily supply, gallons Per Tap	Per capita
Manhattan..	2,149,000	Municipal	Croton	186,000,000	44,000,000	230,000,000	Reservoirs	115	11,369	2,118	13,487	258	122,519(4)	2,028	117
Bronx.....		Municipal	Bronx and Byram	18,500,000	.....	21,000,000	Reservoir	190	4,870	14,854	21,488	260			
		Private	Surface and Ground		1,500,000(3) 1,000,000		Stand-pipe		1,764						
Brooklyn ..	1,256,178	Municipal	Surface		63,938,000	102,963,000	Reservoir	170	13,368	21,476	39,710	165	110,740	927	82
			Ground		31,969,000		Reservoir	198							
							Tower	278							
		Private	Ground		6,756,000		Reservoir Stand-pipe	150	4,806						
Queens.....	133,393	Municipal	Ground		3,892,000	12,925,000	Stand-pipe		2,770	68,014	76,659	200	15,493	836	97
		Private	Ground		9,033,000		Reservoir Stand-pipe	125	5,875						
Richmond ..	69,236	Municipal	Ground		80,000	5,190,000	Stand-pipe		202	33,117	36,600	300	7,263	714	75
		Private	Ground		5,110,000		Reservoir Stand-pipe	215 251	3,281						
Totals.....	3,607,900			204,500,000	167,278,000	371,778,000			48,365	139,579	187,944	——	——	——	103

(1) From Reports of Board of Health. (2) From Report of Mr. L. B. Ward. (3) This is Bronx water sold to the New York and Westchester Water Co. (4) Computed by Mr. Croes. *Above sea level.

that is preventable, except that it is very large, the committee continues as follows:

Mr. Crowell considers that the "theoretically preventable waste" amounts to 120,000,000 gallons daily. Mr. Croes estimates the total waste at 150,000,000 gallons daily, of which 30,000,000, he thinks, is wasted inside of houses and 120,000,000 under ground. The latter he considers could be reduced to 70,000,000 gallons daily by the year 1950.

We believe that a complete cure for leakage below ground could only be found by putting the mains in subways, accessible to detect and repair leaks. The leakage can, however, be materially diminished by certain other recognized methods of detection; but all of these methods are costly and slow of development. No great saving could be hoped for inside of twenty years.

The amount of water wasted inside of houses is considerable, but it cannot even approximately be separated from the leakage below ground. There is no question regarding the possibility of quickly saving part of this waste by metering the water in all large houses.

We should, however, not be oblivious of the fact that in houses having careful consumers the expense of a meter service might be greater than the actual cost of the water usually wasted. While a proper discrimination should, therefore, be made, it is an entirely safe plan in all cases to give the municipal government the right to place a meter in any house where it may deem it desirable, and, on the other hand, to give any user the right to demand a supply by meter measurement, if he desires it.

We cannot, therefore, share Mr. Croes' final conclusion that pari passu with the increased use of water the waste can be gradually reduced to such an extent that the present supply from the Croton River will be sufficient for Manhattan and Bronx for the next fifty years. While such a result would be highly desirable, we do not think it sufficiently probable of attainment to advise any postponement in the construction of works for an additional supply.

It seems to us that reasoning based on waste suppression in other cities is not conclusive, and we cannot compare European cities in this respect with our own cities. The habits of people as regards the use of water are not only different in the two countries, but they are so well fixed that they cannot be suddenly changed.

It is a well known fact, ascertained by meters, that in the houses of the wealthier classes there is a very much greater per capita consumption than in the houses of the poorer class, ranging from several hundred in the former to but a few gallons per day per individual in the latter class. Districts inhabited by the former, therefore, require much more water than districts inhabited by the latter. The same difference extends to entire cities. Those like Fall River and Woonsocket, quoted so often as having a small per capita water consumption, are cities having a preponderance of the operative class whose average wealth and opportunities for luxuries are small. Boston, New York, Philadelphia, Washington, Chicago and other large cities of wealth, have and will always have a large per capita domestic consumption, irrespective of the water used for power and manufacturing purposes. Another reason for the difference is the existence of greater facilities for exercising control in a smaller than in a larger city.

It is certainly true that much water is now wasted, partly through carelessness, partly through leaks in service pipes and mains, indicating that a decrease is possible. But it is also true that there is an undoubted and a perfectly legitimate increase in the amount of water actually used in those cities where the standard of living is raised and where water is more and more employed for power and producing purposes.

The conditions in New York, therefore, seem to us to point towards a legitimate and desirable increase of supply per capita. With this prospect in view, it becomes imperative not merely to reduce the waste as far as practicable, but also to look forward to a bountiful legitimate supply for the future, if the same can be economically obtained.

Additional Water Supply.—The conclusions under this head open as follows:

I. That the Borough of Brooklyn and a portion of the Borough of Bronx are in urgent need of provision for increasing their supply at the earliest possible day, and the other boroughs require an increase within not many years, leaving at present but a short time to prepare for and construct the new works.

II. That the quality of the water should be of as high a degree of purity as practicable, such as is furnished by spring water, filtered wafer or surface water from almost uninhabited and uncultivated mountain regions.

III. That the source of supply should be capable of yielding at least 400,000,000 gallons daily, and of economically furnishing at least one-half of this quantity at the outset.

IV. That the available sources of supply for the city, yielding large quantities of water of the requisite purity, the most economical are: (1) Ten Mile and Housatonic Rivers, a gravity supply; a part of the water to be filtered. (2) The Wallkill River in Orange county; the water to be filtered and delivered by gravity. (3) The Hudson River above salt water influence (i. e., above Poughkeepsie); the water to be pumped, then filtered and delivered by gravity. (4) Several streams in the Catskill Mountains; the water to be filtered and delivered by gravity. (5) The North Hudson, filtered, and Schroon Lake in the Adirondacks, in its natural condition; to be delivered by gravity.

V. That the ground water of Long Island is not sufficient in amount to supply the entire metropolis, nor can the available quantity be supplied at as low a cost as the same quantity from other sources. But the pressing needs of the Borough of Brooklyn can most speedily and most economically be satisfied by a farther extension of the present ground water supply, until a more economical source on the mainland becomes available. (1) That the entire city of New York can be supplied from the Ten Mile and Housatonic rivers, which can deliver 750,000,000 gallons daily. But this source being chiefly in the State of Connecticut, is surrounded with legal difficulties, the nature of which, we are informed by the legal committee, render it impracticable. (2) That second in order of economy is a supply from Wallkill River, from which 460,000,000 gallons daily may possibly be procured. The quality of this water is impaired by the presence of limestone and by muck beds too deep to be removed. One-fifth of the area of the reservoir is located in the State of New Jersey, where, we are advised by the legal committee, the right of condemnation cannot be exercised. (3) That we have a supply in the Hudson River at a point above salt water contamination, whence daily more than 1,500,000,000 gallons could be pumped, but of which a supply of only 500,000,000 gallons daily has been investigated by us. (4) That there is available a daily supply of possibly 460,000,000 gallons from the Esopus, Catskill and Schoharie creeks, in the Catskill Mountains. Doubts exist as to the foundations for some of the dams and as to the possible leakage of the reservoirs, which can only be solved by further investigations. (5) That the Adirondack Mountains can yield a daily supply of over 1,000,000,000 gallons, a project to furnish one-half of which we have investigated at Schroon Lake, and at Hadley, on the North Hudson, 29 miles below.

VI. That all of the above sources can be developed and economically utilized within a few years to furnish 250,000,000 gallons daily until more is wanted.

VII. Our final conclusion is: That the water of the Adirondack mountain region can supply purer water and more of it, than by any other project examined by us. This source lies entirely in the State of New York, and has no complications of inter-State ownership.

There are two methods by which this water can be obtained—one is by pumping the water of the Hudson River at Poughkeepsie into filtering basins on the adjacent high lands, and letting it flow thence by gravity to New York. The other plan is to take the water from the North Hudson near Hadley, and let it flow to New York through longer aqueducts by gravity alone. Both projects require the construction of storage reservoirs in the Adirondacks to equalize the seasonal flow. This source is by far the largest investigated by us and can supply from 1,000,000,000 to 1,500,000,000 gallons daily, which is enough with the present Croton system to supply the wants of a population of from 13,000,000 to 18,000,000 persons.

In comparing the two methods, we find that the final supply taken at Poughkeepsie would be the greater by the amount coming from streams below Glens Falls.

The water taken from the upper Hudson would be purer than that taken at Poughkeepsie, which is below the drainage of many cities. The Poughkeepsie water would have to be filtered at once, and the North Hudson water (with the exception of Schroon Lake), would have to be filtered eventually to remove discoloraton and taste from swamps and the refuse of mills, unless its purity could be maintained by turning the whole water-shed into a State Park, where pollution could possibly be prevented.

The Poughkeepsie water would be pumped into a reservoir at such an elevation that it could flow by gravity, reaching New York at an elevation of 260 ft. above sea level. The water taken from the North Hudson at Hadley would flow by gravity to an elevation of 310 ft. Both projects would improve the navigation of the Hudson below Troy, and increase the water-power of the river above, by equalizing the seasonal flow. The Poughkeepsie project would be the more efficacious in improving navigation, as no water would be taken out of the river above Poughkeepsie.

To furnish 250,000,000 gallons daily from Poughkeepsie, the first cost would be $36,880,000; the yearly cost would be $2,585,000; cost per 1,000,000 gallons, $28.33. To furnish 500,000,000 gallons, the first cost would be $72,374,000; yearly cost, $5,546,000; cost per 1,000,000 gallons, $30.39.

To furnish 250,000,000 gallons from the Adirondacks, the first cost would be $71,727,000; the yearly cost, $2,727,000; cost per 1,000,000 gallons, $30. To furnish 500,000,000 gallons, the first cost would be $140,155,000; the yearly cost, $5,338,000; cost per 1,000,000 gallons, $29.25.

We estimate that the shortest probable time between letting contracts for the work and the first use of the new aqueduct would be for the Poughkeepsie project six years, and for the Adirondack project seven and a half years. The surveys and preparations for letting the work could and should be made coincidentally with the legislative and legal preparations.

All the estimates providing for a supply of 500,-

TABLE II.—DATA CONCERNING AVAILABLE ADDITIONAL WATER SUPPLY FOR GREATER NEW YORK, DELIVERED AT CITY LINE.
(Installation for 350,000,000 gallons daily from the Ten Mile and Housatonic Rivers and 250,000,000 from the other sources.)*

Name of source.	Character of water.	How delivered.	Elevation of delivery Ft. above sea level.	Length of aqueduct, miles.	Drainage area, sq. miles	Cap., million galls. daily.	Cost of construction	Ann. op. exp., int. and maintenance.	Cost per 1,000,000 galls.
Ten Mile and Housatonic Rivers (1)	150,000,000 galls. filtered.	Gravity	300	36	1,020	350	$46,000,000	$1,917,000	$15.00
Wallkill River (2)	Filtered	Gravity	310	48	465	250	36,827,000	1,652,000	18.10
Hudson River, above Poughkeepsie (3)	Filtered	Pumped	260	60	11,800	250	36,880,000	2,585,000	28.33
Esopus and Catskill Creeks (4)	Filtered	Gravity	310	100	437.5	250	59,653,000	2,498,000	27.35
Adirondack. Schroon Lake (5)	Natural	Gravity	310	203	518	250	71,727,000	2,727,000	30.00
(Installations Ranging from 460 to 750 Million Gallons Daily.)									
Ten Mile and Housatonic Rivers (6)	150,000,000 galls. filtered daily.	Gravity	300	36	1,020	750	$52,000,000 67,000,000	$2,125,000 3,245,000	$8.00 11.86
Wallkill River (6)	All filtered Filtered	Gravity	310	48	512	460	62,534,000	2,778,000	16.54
Hudson River, above Poughkeepsie (7)	Filtered	Pumped	Half at 131.5; and half at 260	64 60	11,800	500	72,374,000	5,546,000	30.39
Esopus, Catskill and Schoharie Creeks (6)	Filtered	Gravity	310	100	742.9	460	118,881,000	4,838,900	28.82
Adirondack. Schroon (7)	Natural	Gravity	310	203	518	500	140,155,000	5,337,900	29.25
Hadley (7)	Filtered	Gravity	310	174	4,500	500	140,155,000	5,885,400	32.25

*If the Ten Mile and Housatonic rivers system should be constructed, with a daily capacity of 350,000,000, but should temporarily be used only to the extent of a daily delivery of 250,000,000, the resulting cost per million gallons delivered would be $21, which would be reduced to the above figure of $15 when the rate of delivery is increased to 350,000,000 gallons per day. But, when the other systems supply 350,000,000 gallons per day, the resulting costs per million gallons delivered would be respectively about $20, $30, $35, and $40.

(1) Estimates of cost made by Mr. John R. Freeman, but modified by this committee. Aqueduct has capacity to deliver, in addition, 50,000,000 gallons from Croton basin. Ten Mile River water is filtered. (2) Reservoir stripped in a few places. One aqueduct. (3) One aqueduct. Annual cost could be largely reduced by rent of water power in Adirondacks. (4) One aqueduct. (5) Estimates of cost made by Mr. John R. Freeman, but modified by this committee. Aqueduct delivers 800,000,000 gallons daily. (6) Two aqueducts. (7) Two aqueducts. A large credit available for water power. Supply may be increased to over 1,500,000,000 gallons daily. (6) Two aqueducts. (7) Two aqueducts. Capable of increasing supply to over 1,000,000,000 gallons daily from over 4,000 sq. miles.

000,000 gallons a day were based on duplicate aqueducts. None of the estimates include an allowance for a sinking fund, the reason for which is given as follows:

> We omitted this because a comparison between the projects requiring a large investment with small cost of operation and those requiring a smaller investment with large cost of operation would manifestly become unfair. We have, however, added a sufficient sum for maintenance and renewals to provide for keeping the works permanently in proper repair and good order.

The estimated costs of the various projects, with other data relating to them, are given in Table II. Common labor is placed at $1.35 a day in these tables, as the entire work is outside the city and would probably be done by contract, but estimates were also made on the basis of $2 a day for labor.

It will be noted that most of the estimates are for filtered water, the exceptions being unpolluted water from sparsely inhabited mountain drainage areas. This, the committee believes, is wholly in accord with modern practice and tendencies, it having assumed that the people of New York "would not be satisfied with any new source of water supply that is not equal to the highest standard now set in any other city." The cost of filtration, including interest, ranges from $4.23 to $6.91 per 1,000,000 gallons for the various projects.

As to the quantity of water to be provided, the committee states that it did not attempt to fix either per capita rate of consumption nor a time limit, believing that any new source should at least double the present source of supply.

What the committee says as to pressure is so important that we reprint most of it, as follows:

> In the several projects considered, those which bring the water into the city by gravity can, as well as not, deliver it for all the territory at a high elevation, which we have fixed at 310 ft. above tide.
>
> The project requiring pumping from the Hudson River should deliver the water at no greater height than necessary, and it was decided to deliver a portion of the Hudson River supply at 131.5 ft., and another at 260 ft. above tide. A small portion will require a further lift into the highest districts of a limited area, to nearly the same extent as required at present.
>
> We are of the opinion that it would be unwise to materially increase the present pressure in the lower part of Manhattan, where the high buildings are increasing in number. It is impracticable to deliver water to the highest floors of these by gravity. Therefore, some of it must in any event be pumped.
>
> A material increase of pressure would not only require a remodeling of much of the plumbing, but would cause a large increase in the unavoidable waste of water and a correspondingly large increase in its consumption. After the new aqueduct was brought into service with a better pressure the consumption at once increased about 30.8%, which increase was almost wholly due to the greater pressure.
>
> On the other hand, the only advantage from an increased pressure is the better fire service. Yet, our examinations point to the fact that a still greater advantage can be obtained at less cost by a separate salt water fire service in the important districts.
>
> We have, therefore, assumed that of the water brought in by gravity at an elevation of 310 ft., as much of it as may be required by the low service would flow into the present reservoirs, and that the high-service districts would be supplied as far as practicable directly from the aqueducts.

Lakes George and Champlain and the Great Lakes are dismissed by the committee as impracticable. Lake George is only 323 ft. above sea level, and therefore too low for a gravity supply; besides which it would require an aqueduct 180 miles long to deliver a daily supply of not over, and probably less than, 227,000,000 gallons, according to Mr. Rafter. Lake Champlain is 222 ft. lower than Lake George. As to the Great Lakes, the committee says:

> A supply from Lake Ontario, which is about 247 ft. above sea level, would require an aqueduct over 300 miles long and require the water to be pumped nearly 400 ft., if delivered at 300 ft. above sea level in New York.
>
> A supply of water from Lake Erie, which is about 580 ft. above sea level, could be obtained advantageously if the proposed Erie Canal enlargement were so located that the canal could be fed throughout from Lake Erie. Yet the canal as proposed could not deliver more than 230,000,000 gallons per day, and this practically at tide level when reaching Troy.

The use of salt water for extinguishing fires, the committee says, would be valuable chiefly through affording a better pressure and improved fire protection, rather than as a means of saving fresh water, the quantity of water thrown on fires in Manhattan and the Bronx being estimated at only 46,000,000 gallons a year.

Since "32% of the water thrown on fires is now drawn by the fireboats from our rivers without regard to sewer outlets and without complaint of damages" to merchandise there can be but little valid objection to the use of water from this source, except that it adds one more line of street pipes. The use of salt water for street sprinkling would effect a saving in fresh water. This may be appreciated more fully when it is remembered that there are now 760 miles of macadamized streets in Greater New York, 620 miles of unpaved roads, and hundreds of miles yet to be laid out in the sparsely settled districts. The committee says the use of salt water for sprinkling "not only offers relief from fears of a lack of supply, "but as salt water is some three times as effective both in binding the surface of macadam and laying dust, its use would result in a decided economy, as compared with the use of fresh water." Another great opportunity to use salt water, which is believed to be quite out of the question with the more expensive fresh water, is flushing the streets, both for cleansing and cooling. Wards 10, 11, 13 and 17, with a total area of 697 acres, had a population of 201,000 in 1895, or 474 per acre. The health board estimates that the infant mortality (deaths under five years) in these four wards in 1898 was 47.4% of the total mortality, against 39% for the whole borough. The population of the whole borough has an average per capita area of 340 sq. ft., against 92 ft., in these four wards, the figures in each case including streets, parks and yards, as well as buildings. In this particular section, a large part of the pavements are of asphalt, making it particularly feasible to keep the streets clean by flushing, while the necessity for the greatest possible cleanliness in all particulars is shown by the density of the population.

The reports of the several engineers occupy 300 of the 400 pages devoted to the work of the engineering committee. We will attempt to bring out some of the most salient points in these reports, each one of which contains a large amount of interesting and valuable information.

The History, Condition and Needs of the New York City Water Supply and Restriction of Waste of Water.

By J. J. R. Croes, M. Am. Soc. C. E.

The historical portion of this report must be passed over for lack of space. The safe capacity of the Croton drainage area, Mr. Croes places at 280,000,000 gallons a day, or 5,000,000 gallons in excess of Mr. Freeman's estimates. On this basis the period of depletion "successive filling and overflow" of the storage reservoirs would have exceeded two years only twice during the past 30 years. This safe daily yield, however, is based on the supposition that the water continues to be supplied without filtration. With filtration, and delivery to the consumer without exposure to the air, the safe daily yield might be made 350,000,000 gallons, provided the storage capacity was increased to 150,000,000,000 gallons, or a little more than doubled. Mr. Croes recommends that estimates be made to show whether the cost of 70,000,000 gallons a day, developed in this way, would be less than a supply from some other source. In considering such a proposition, it should be remembered that Mr. Croes believes the present supply would be available for years to come, if only the waste were cut down as it might be. But it must not be forgotten that this 280,000,000 gallons a day cannot be delivered above the 160-ft. level, and that it affords ample pressure for all that part of Manhattan and the Bronx lying below Elev. 60. In fact, Mr. Croes says, in this area a supply under a greater head would require "an entirely new and separate system of distributing mains and plumbing in the buildings." while a supply under 200 to 300 ft. head (above sea level) "could only be used on the west side of Manhattan above 34th St. and in the upper portion of the Bronx, to which the Croton supply will not rise by "gravity."

As to Brooklyn, it needs "water from some other and distant source" at once, while Queens and Richmond boroughs can probably get along with near-by ground water sources for some years to come, but after 25 years, at the most, "it will not be safe to place any dependence upon water obtained within the limits of" those two boroughs. For Brooklyn and Queens, Mr. Croes recommends a new supply "from sources outside the city," with a daily capacity of at least 300,000,000 gallons, delivered in the city at an elevation of 170 to 200 ft. above tide.

The most interesting part of Mr. Croes' report is devoted to waste. This he considers under the two heads of underground and house leakage. He believes that there are at least 18,000 old, unused, service pipes attached to the 850 miles of mains in New York city, thousands of which are leaking continuously. In addition, many of the 500,000 joints in the distributing mains are leaking all the time, some of them in large quantities. The records of leaks discovered show that they increase with accessions to pressure, this being particularly noticeable after the new aqueduct was put in use, and again after new and larger feeding mains were laid in Fifth Ave. and Elm St. He places the use of water for public purposes at 15,000 gallons a mile, which for the 850 miles of mains in old New York amounts to 12,750,000 gallons, or six gallons per capita. About 30% of all taps in Manhattan and the Bronx were metered on Jan 1, 1900, or 36,068. The public records for some years past, as well as those for nearly 600 meters of all classes read by a private inspector, indicate that the consumption per meter has run for some years, and is likely to continue, at about 1,450 gallons per metered tap per day. Mr. Croes assumes that none of this water is wasted, or at least that if wasted it is accounted and paid for. The fact that the average supply of water per metered tap diminished slightly from 1889 to 1899, while that supplied to unmetered taps increased in the same period from 907 to 2,248 gallons a day, or more than doubled, Mr. Croes believes is very significant, particularly when taken in connection with the increase in pressure during the same period, already noticed. He says:

> If the increase of pressure had increased the legitimate use of water in the metered buildings, it would have shown in the records of measured water. That it did not increase such legitimate use, but merely increased the waste from orifices either undiscovered or left open by design, is clearly established by the fact that where such orifices did not exist the use of water did not increase.

In order to study the consumption and waste from unmetered taps, 25 meters were set in residences in Manhattan, early this year, and 12 in Brooklyn, under Mr. Croes' direction. He presents detailed figures showing the character of the houses and the result of the readings for the first three weeks. In 18 of the houses, the per capita consumption ranged from 29 to 89 gallons a day, the average being 51 gallons. In the remaining eight houses, the consumption ranged from 83 to 391 gallons per capita per day, averaging 166 gallons. Taking the 25 houses together, the average daily consumption was 91 gallons. After pointing out bad sources of leakage the consumption was reduced very materially, so that for a second three weeks the per capita consumption for the 25 houses was only 66 gallons, a saving of 25 gallons per capita per day. Mr. Croes says that the 25 houses represent very fairly the average of unmetered residences in New York, and concludes from these records that 50% of the unmetered water is wasted. He states that the average number of occupants per house, 9.72, is only 35% of the average for the city, estimated by the health department at 22, but says that "the use of water in residences of this class is far greater in proportion to the number of occupants than in dwellings of a less expensive character," besides which, "a majority of the tenement houses in Manhattan are metered already."

From the foregoing and other data Mr. Croes deduces Table III., showing the distribution of use and waste of water in New York city.

Table III.—Distribution of Water Consumption in Manhattan.

	Miles of Sts.	Number of services.	Gallons per day.	Total gallons.	Per-c't'ge of total.
Metered water..... ...		35,755	1,450	51,844,750	21.10
Unmetered water.. ...		86,764	355	30,801,220	12.54
Public purposes .. 850	.....		15,000	12,750,000	5.11
Total actually used.....				95,395,970	38.75
Amount delivered to mains.....				245,700,000	100.00
Amount wasted				150,304,030	61.25
Deduct from this latter figure amount of waste from unmetered services—86,764 × 355 (20% of the waste)....				30,801,220	12.54
Leaving the amount unaccounted for, and which must be wasted from the main pipes without reaching the surface of the ground (80% of the waste)*.....				119,502,810	48.71

*This waste amounts to 142,000 gallons per day from each mile of main pipes in use.

Boston accounts for 73% of the water delivered, and Fall River accounts for 76%, the daily underground leakage being 14,187 and 10,000 gallons, respectively. A saving of 107,520,000 gallons a day would be effected in Manhattan borough if its underground leakage were cut down to the Boston rate, while 25,000,000 gallons a day more would be saved by reducing the house waste by 80%. The consumption would then be:

	Gallons.
Metered water used	51,844,750
Unmetered water used	30,801,220
Public purposes	12,750,000
Waste from mains	11,760,000
Waste from houses	6,000,000
	113,155,970

This, Mr. Croes says, would give an average daily consumption for Manhattan of about 56 gallons per capita, "a supply ample for all purposes." He believes this figure could be attained by means of "the district system of inspection of mains and houses, and placing of meters on all buildings in which water is used." At present, meters cannot be applied to private residences; or rather, the cost of such meters cannot be placed on the consumer. Mr. Croes believes the city has authority to sell all water by meter measurement, if it supplies the meters.

To reduce underground waste Mr. Croes would employ Venturi meters to determine the districts having excessive waste, which, as soon as found, would be remedied. The crusade against waste could be carried on with sufficient speed to keep the demand for water below the supply, allowing say 15 years to eliminate house waste and 40 to 50 years for underground leaks. To this end, 100 Venturi meters might be placed each year at a cost of $60,000 and 10,000 house meters at a cost of $180,000, making an annual construction charge of only $240,000. By allowing an average of 1,500 gallons a day for 30% of the taps and 400 gallons for the balance, all taps to be metered by 1915, and with reduction in the leakage per mile of main, as noted, the total consumption in 1915, 1930 and 1950 would be as follows:

1915.

	Gallons.
46,800 meters at 1,500 gallons	70,200,000
109,200 taps at 400 gallons	43,680,000
Public uses, 1,130 miles, at 15,000 gallons	16,950,000
Waste, 1,130 miles pipe at 100,000 gals. a mile	113,000,000
Gallons per day	243,830,000

1930.

	Gallons.
56,250 meters at 1,500 gallons	84,375,000
131,250 taps at 400 gallons	52,500,000
Public uses, 1,405 miles pipe at 15,000 gallons	21,070,000
Waste, 1,405 miles pipe at 60,000 gallons	84,300,000
Gallons per day	242,245,000

1950.

	Gallons.
68,400 meters at 1,500 gallons	102,600,000
159,600 taps at 400 gallons	63,840,000
Public uses, 1,765 miles pipe at 15,000 gallons	26,475,000
Waste, 1,765 miles pipe at 40,000 gallons	70,600,000
Gallons per day	263,515,000

Comparatively little space is given by Mr. Croes to a study of leakage in Brooklyn. With only 2,880 meters, out of a total of 113,154 services, the average consumption per unmetered service, including all public uses and underground leakage, is 756 gallons a day, against 2,248 gallons in Manhattan. The underground leakage in Brooklyn is estimated at about 60,000 gallons per day per mile of pipe. As has been stated above, Mr. Croes believes that Brooklyn is already in such great need of more water that immediate steps should be taken to develop it, which, with the fact that its consumption is now much lower than that of Manhattan, may account for the fact that he devotes comparatively little space to the conditions in Brooklyn, and advises that a new supply of 300,000,000 gallons a day be developed for Brooklyn and Queens.

The Uses and Waste of Water in New York City.

By Foster Crowell, M. Am. Soc. C. E.

The actual use and incurable waste of water in old New York is placed by Mr. Crowell at 55 gallons per capita per day, divided as follows: Public purposes, 5 gallons; trade, 20; domestic, 30 gallons. The remaining 62 gallons of the 117 gallons per capita indicated by Mr. Freeman's gagings, is classed by Mr. Crowell as theoretically preventable waste, constituting 53% of the total supply and amounting to 120,714,000 gallons per day for old New York. Mr. Crowell support these figures by reviews of data from other cities and studies of waste in New York, including in the latter the meter records, public and private, already noticed under Mr. Croes' report. The data from other cities also includes statistics of European consumption, which, as most of our readers know, show a very small per capita use of water, compared with American experience. Mr. Crowell makes no attempt to divide the waste into its several elements. He concludes his report as follows:

> The experience of other communities which has been cited demonstrates very clearly that all the wastage might be attributed to defective plumbing, etc., without exceeding the reasonable probabilities, but there is probably considerable leakage in the mains and the distribution system also.
>
> The amount of theoretically preventable waste, as has been stated above, is about 53% of the total quantity of water delivered at the present time. The extent to which the prevention can be carried depends upon other considerations than physical laws, and can only be estimated. Under the assumption that the entire consumption can be metered, I should be inclined to estimate the possible saving as a very considerable part of the theoretical amount, dependent upon the thoroughness of official action and the proper education of the public, for every householder would thereupon become directly interested in the reduction of the waste, and the inherent trait of human nature which previously had led him to consider that the more water he used the more value he was getting back from his taxes, would not cause him to feel concerned lest he should suffer by being made to pay for water he did not use. That is the experience in other places where meters have been universally applied, and to a greater or less extent is to be counted upon.*

The Pumping Stations Connected with the Water Supply of New York.

By Lebbens Ward, M. Am. Soc. C. E.

This is a most interesting and valuable description of the means employed to deliver water to the inhabitants of Greater New York, but as it is mainly statistical and as the conclusions reached, so far as they effect the main questions at issue, have been presented in the other reports (see Table I., particularly), we are compelled to pass this report over with little else than these few words of commendation.

The large population of Brooklyn, and the fact that the whole supply of that borough is pumped, are chiefly responsible for the fact that 45% of the water consumption of New York city is delivered by pumping. Again, the nature of parts of the Brooklyn supply, secured from driven well stations, accounts for many of 51 separate pumping stations in Greater New York, 32 of which are municipal and 19 private.

The Sources of Water Supply Suitable for the Future Use of the City of New York.

By Jas. H. Fuertes, M. Am. Soc. C. E.

A summary of a part of the work done by Mr. Fuertes has been given in Table II., showing various facts and figures relating to available new sources of supply for New York. But Mr. Fuertes made studies of many other sources, and his report as a whole will be of great value to all future investigators of the question. As has been shown in our abstract of its report, the engineering committee recommends the Adirondacks as the source of future supply, taking the water either at its origin, or else from the Hudson River, above Poughkeepsie. In point of economy, however, it placed the Housatonic and Ten Mile River, combined, first and the Wallkill second, basing its conclusion as to the first of these on Mr. Freeman's recent report and on the Brooklyn report of 1896. The engineering committee threw out these two sources, on the advice of the legal committee, because of interstate complications. The Housatonic and Ten Mile River plan, as worked out by Mr. Freeman, was described in our abstract of his report, April 19, 1900. As Mr. Fuertes places the Wallkill first, from an engineering point of view (he not having the Housatonic under consideration) and as the committee ranks the Wallkill next after the Housatonic, in point of economy, an abstract of what Mr. Fuertes says about the Wallkill is in order.

The Wallkill rises in northern New Jersey and empties into the Hudson River at Kingston. By building a dam at Phillipsburg a huge reservoir could be formed, flooding a broad valley, only 20 to 30% of which is now wooded, only 20% of which is or ever has been cultivated and a large part of which is flooded during the spring rains. We have condensed Mr. Fuertes' description of this reservoir and some other parts of the scheme to read as follows, retaining his language throughout:

> It is proposed to erect a dam at Phillipsburg, which will impound the waters of the river and flood these drowned lands from 20 to 30 ft. in depth. The general elevation of the valley is about 390 ft. above sea level. A dam which would raise the water level to Elev. 410 would provide sufficient storage to make possible a daily draft of 250,000,000 gallons by drawing the water in the reservoir down 5 ft. This would leave 15 ft. of water over the bottoms at the lowest level to which it is drawn. The area of the watershed above Phillipsburg is 465 sq. miles. The area of the land submerged at Elev. 405 is 48.9 sq. miles, and at 410 it is 51.4 sq. miles, showing that only about 5% of the area is exposed by drawing down the reservoir enough to give a yield of 250,000,000 gallons daily. The amount of water impounded behind this dam would be, approximately, 200,000,000,000 gallons, of which 53,000,000,000 gallons would be available. This amount of storage would assure a daily yield of 615,000 gallons of water per square mile of land surface per day, or 254,000,000 gallons per day.
>
> In view of the large area of the reservoir, and the possibility of algae and lily growths in the shallow places around the edges, it is proposed to filter the water before conducting it to New York. Since it is proposed to filter the water, it will not be necessary to remove the top soil of the submerged portions except in a few places, ample protection being afforded by simply clearing the land, grubbing out the roots, burning the grass and debris and then giving the area a general cleaning.
>
> * * * * * * * * * *
>
> By increasing the height of the Phillipsburg dam, thereby raising the water surface to 422 ft. above sea level, the flooded area will be 58 sq. miles, and the available storage capacity of the reservoir, when drawn down to Elev. 402, will be 219,000,000,000 gallons; with this available storage the minimum yield in dry years will be about 417,000,000 gallons daily. When the reservoir is full the total amount of water impounded will be 387,000,000,000 gallons, and when drawn down to its lowest level to yield 417,000,000 gallons daily, the water will stand 12 ft. deep over the entire flat portion of the valley.
>
> This reservoir would be the largest artificial reservoir in the world, and would take, after closing the gates, about 500 days to fill.
>
> By diverting the waters of Shawangunk Creek into the reservoir through a tunnel 18 ft. in diameter, leading from Bloomingburg to Mechanicstown, a distance of a little over six miles, 47 sq. miles may be added to the watershed and the Wallkill reservoir may be made to yield about 460,000,000 gallons daily in dryest years, and over 500,000,000 gallons in ordinary years.
>
> It may be said, against this project, that the construction of the Phillipsburg dam will cause the flooding of lands in New Jersey, and that objections might be raised in that State. It may be answered, however, that the Wallkill, although rising in New Jersey, flows into New York State, and that New York is entitled to the flow of the river, in the same manner that New Jersey claims the right to the waters of the Ramapo, Mahwah and other streams rising in New York, but flowing into New Jersey. It would seem, in view of the importance of the streams in the Ramapo Mountains as possible future water supplies for the metropolitan district of New Jersey, that an amicable agreement could be reached between the two States that would make it possible for each to avail itself of the needed watersheds in the other State, instead of both being deprived of these benefits by reason of inability to exercise the right of eminent domain in the acquisition of and holding of property for reservoir sites.

The proposed filter beds would be located "some distance" below the dam, but at such an elevation that the water would flow by gravity from them to a covered reservoir at the city line, 310 ft. above sea level.

The filter beds would have a reserve area of 20% and would work at the rate of 3,000,000 gallons per acre per day. Each bed would have an area of ¾ acre and would be covered. All power required at the beds, for sand washing and for lighting, would be developed by turbines.

Besides being cheaper than the Adirondack supply, Mr. Fuertes says the filtered Wallkill would be superior in quality. The cost of water from the Wallkill also possesses the great advantage of being less than the present cost of pumping the Brooklyn and Staten Island supplies.

A Water Supply from the Adirondack Mountains for the City of New York.

By Geo. W. Rafter, M. Am. Soc. C. E.

The scheme considered by Mr. Rafter involves the development of a supply of 500,000,000 gallons a day, by building a single large reservoir on the Schroon River at Tumblehead Falls, 14 miles above the Hudson, to develop a storage of 18 ins. of rainfall* from 518 miles of drainage area. This would give a total storage of 162,248,000,000 gallons, at an elevation of 850½ ft. above the sea. The necessary dam would be 70½ ft. high, and the reservoir, when full, would cover 26.4 sq. miles. To save damage to water power, the water from the reservoir would flow down the Schroon River

*We have limited our abstract of Mr. Crowell's report to his conclusions in order to give more space to his other report, presented further on, this seeming all the more feasible because of the full discussion of waste by Mr. Croes.—Ed.

*The engineering committee raises a question as to developing so much of the rainfall.—Ed.

a few miles to a diversion weir, before entering the aqueduct (see Table II.). The estimated cost of this reservoir, allowing $1,000,000 for land damages, is $3,000,000, but 10,639 HP., gross, would be developed for use in the Schroon valley. On the other hand, water power in the Hudson valley, all the way to Troy, would be affected, the total decrease being estimated at 14,695 HP., net, or nearly 30% of the total, the value of which is placed at $4,761,000. This is based on a diminution of available flow of 550 cu. ft. per sec., the total supply diverted being about 750 cu. ft. per sec.

Mr. Rafter says that compensating reservoirs might be constructed for less than the estimated value of the lost horse-power. Although legal decisions in water diversion cases in this country have been against compensation in kind, Mr. Rafter thinks the local conditions in the Hudson drainage area are such that this principle might be applied there. He estimates that for $1,000,000 a number of storage reservoirs, capable of furnishing 550 cu. ft. per sec., might be built, thus saving $3,761,000, as compared with money compensation. If money had to be paid, the cost of the Schroon River scheme would be nearly $8,000,000.

Mr. Rafter also considered a reservoir system for regulation only, to be supplementary to the scheme for taking water from the Hudson at Poughkeepsie. From previous calculations, he believes that 50,000,000,000 cu. ft. of storage might be secured on the Upper Hudson for less than $100 per 1,000,000 cu. ft., thus keeping the fresh water flow of the Hudson at Albany up to 5,000 to 6,000 cu. ft. per sec., against an occasional minimum of 2,000 cu. ft. at present.

An Auxiliary Salt Water Supply for Fire Protection, Street Washing, Sewer Cleaning and Other Purposes.

By Foster Crowell, M. Am. Soc. C. E.

Owing to the low gravity pressure throughout a large part of old New York, and the fact that the present distributing mains are not suited to a heavier pressure, combined with the good results obtained with separate fire lines in Cleveland, Milwaukee, Detroit, Buffalo and Boston, and the fleet of fire boats already in New York, Mr. Crowell recommends the installation of a salt water fire protection system for a limited section, in order to give it a trial.

If the system proved successful, it might be extended in Manhattan, a portion of the Bronx and perhaps in Brooklyn.

After describing in detail the fire lines in the cities mentioned above, the descriptions being based largely on personal investigations, Mr. Crowell sets forth the advantages of salt water fire protection for New York: (1) The usefulness of the fire boats would be greatly increased by the substitution of pipe for hose lines, enabling them to cover a much greater area. There are now four fire boats in Manhattan and two in Brooklyn, with capacities ranging from 3,500 to 13,000 gallons per minute, and a joint capacity of 39,300 gallons per minute. The boats are now "eating their heads off," since they must be in constant readiness for service, but are used only a small fraction of the time. A salt water system would often diminish the time required to get water on the fire and the great volumes available are of immense advantage. Such a system would make a roof fire service readily available, through the use of stand-pipes, and it might afford a ready means of "cleansing streets and flushing sewers at a very moderate cost."

The first step towards the installation of a salt water system would be to construct separate pipe lines and branches, to be supplied by fire boats. These might be developed, if experience warranted it, into a general system of salt water mains, supplied from permanent stations, a change which would be desirable, or necessary, if salt water was adopted for continuous use for a variety of sanitary purposes. The area of Manhattan below 23d St., is 2,919 acres, of which some 500 acres can be reached by the fire boats. The remaining 2,400 acres, Mr. Crowell estimates, could be provided with a fire pipe and hydrant system for $2,400,000, exclusive of permanent pumping stations. For first-class systems, 14-in. cast-iron supply mains would be used, with 12-in. secondary mains and 8-in. cast-iron stand-pipes and connections, tested individually to 600 lbs. per sq. in. and as a whole to 400 lbs., with 180 lbs. working pressure. Hydrants with three hose and one steamer connection would be placed 150 ft. apart.

Systematic street washing, with either salt or fresh water, is practically untried in America. Mr. Crowell presents some facts as to this practice abroad, all of which, he thinks, are favorable to its introduction here, but the experience cited was with fresh water. Facts are presented showing satisfactory experience in Boston, Cambridge, Alameda, Cal., and San Francisco, and in a large number of English cities with salt water for street sprinkling. Mr. Crowell thinks salt water would be particularly valuable for sprinkling macadamized streets.

Some facts are presented tending to show that with a cheap supply of salt water great benefit could be effected in the crowded sections of the city by using water to cool the pavements in very hot weather. To throw light on the possible use of salt water for large offices, circulars were addressed to a number of shipping firms to learn whether their use of it for sanitary purposes gave satisfaction. The replies were practically all in favor of its use.

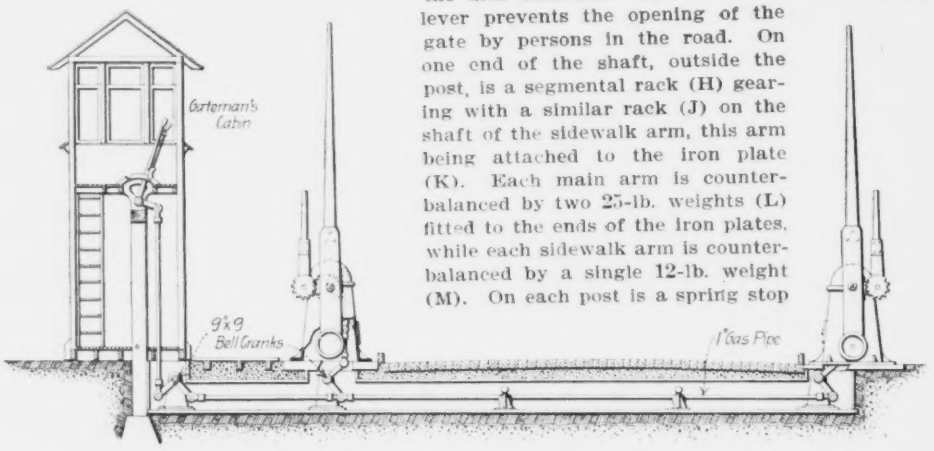


FIG. 1.—PIPE-CONNECTED GATE FOR GRADE CROSSINGS.
Wilson Railway Gate Co., Makers.

RAILWAY CROSSING GATES WITH PIPE CONNECTIONS.

Grade crossing gates of the ordinary type, having arms extending across the road and sidewalk, are very generally operated by wires or by compressed air, but we illustrate herewith a gate which is operated by pipe connections and levers similar to those of an interlocking plant. In the gateman's tower is placed a signal lever, fitted with sector, latch and latch handle, and connected by 1-in. gas pipe and bell cranks 9 × 9 ins., with the operating mechanism of the gate arms. The bell cranks have ⅞-in. turned pins, and the pipe under the roadway is supported by ordinary pipe carriers as used in interlocking work. The general arrangement is shown in Fig. 1. Each gate arm is carried by a hollow cast-iron post or casing which contains the mechanism and has a moveable top.

Fig. 2 shows the details of the mechanism. The vertical pipe from the bell crank under the post is connected to a vertical malleable iron bar (A) having a rack cut in one edge, while the back of the bar is supported by two rollers (B) (B) fitted between the guides. The rack meshes with a segmental rack (C) keyed upon the gate shaft. This shaft rests upon two anti-friction rocker bearings (D). Two iron plates (E) are keyed to the ends of this shaft, outside the post, and to these are attached the wooden arms forming the main gate. Pivoted between the ends of the plates is a gong, having the hammer (F) which engages with a ratchet (G) and thus rings the gong as the arm descends. The latch on the operating lever prevents the opening of the gate by persons in the road. On one end of the shaft, outside the post, is a segmental rack (H) gearing with a similar rack (J) on the shaft of the sidewalk arm, this arm being attached to the iron plate (K). Each main arm is counterbalanced by two 25-lb. weights (L) fitted to the ends of the iron plates, while each sidewalk arm is counterbalanced by a single 12-lb. weight (M). On each post is a spring stop (N) which acts as a buffer for the arms when they are raised to the end of their travel. The pipe makes a stroke of 7 ins. to turn the shaft 90° and thus close or open the gate. To prevent freezing of the connections, the post and pipe box are drained by pipes leading to a sewer or drain.

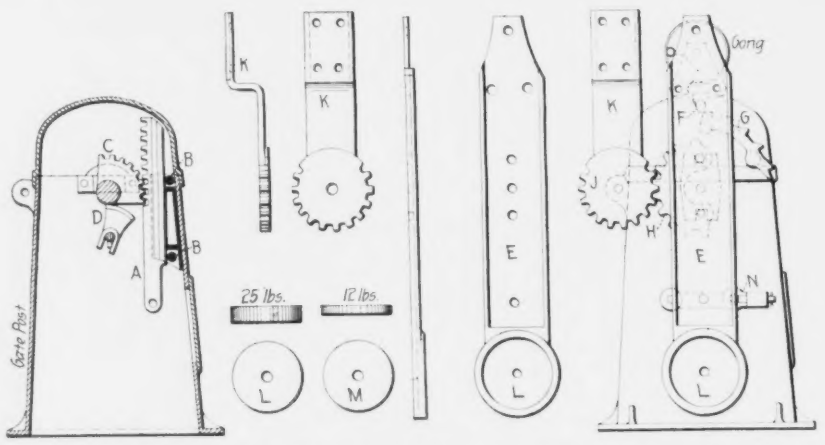
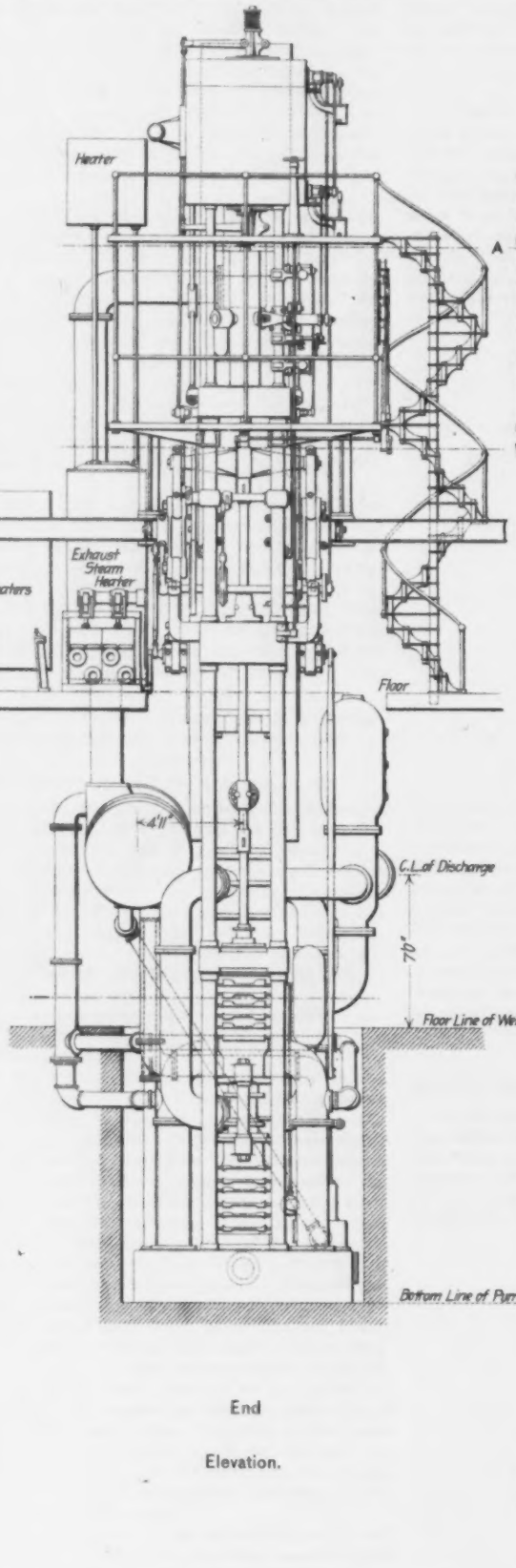


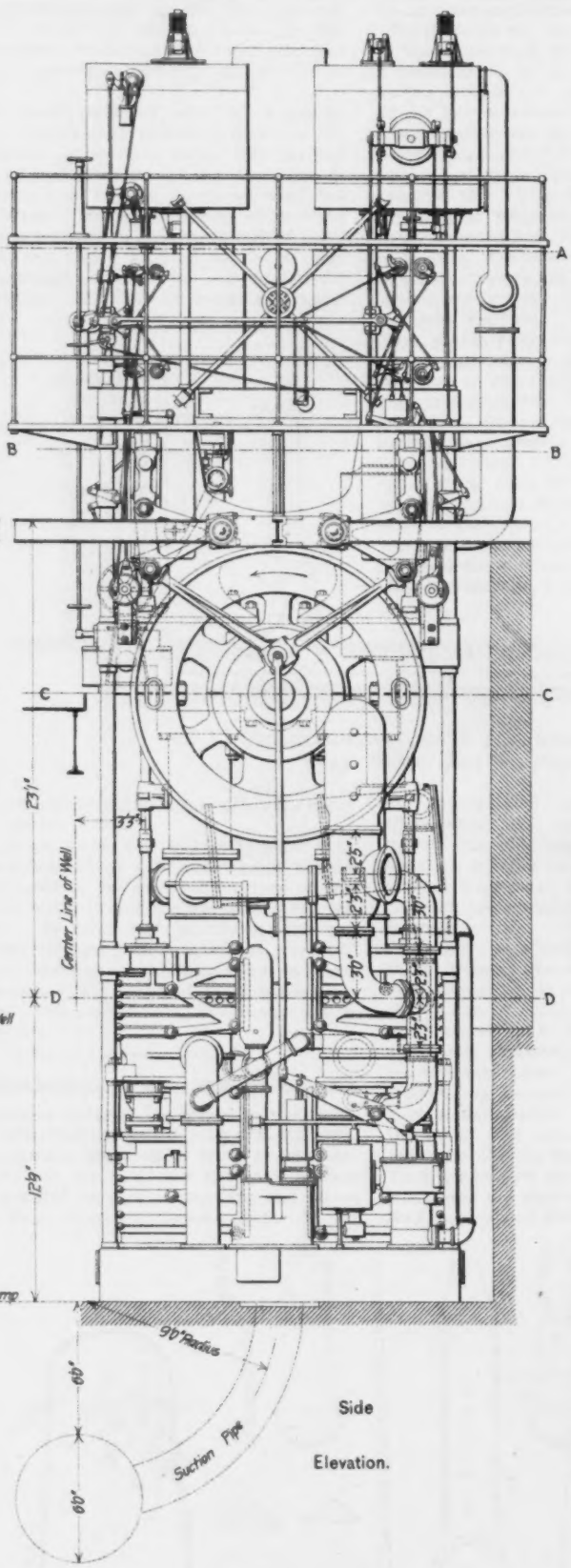
FIG. 2.—DETAILS OF WILSON GATE FOR GRADE CROSSINGS.

This gate was invented some years ago by Mr. H. C. Wilson, who was then (and for 14 years) Signal Engineer of the Grand Trunk Ry., and had charge also of all crossing gates. Having experienced considerable difficulty in keeping the ordinary gates in service during the bad weather, he conceived the idea of making the mechanism from interlocking material then in stock. The results were so satisfactory that others were made, and the design was patented, but the gates were not put upon the market until about two years ago. They are now in use on a number of leading railways, and are manufactured by the Wilson Railway Gate Co., of Birmingham, Mich., of which Mr. H. C. Wilson is manager. The advantages claimed are reliability, positive action, and economy in maintenance. The company also manufactures mechanical and electric signals for road crossings, and derails and signals for railway crossings at grade.



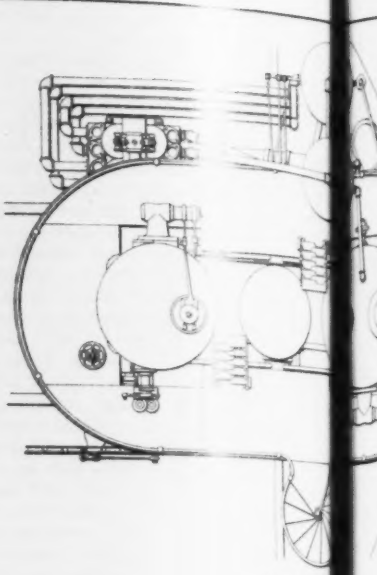
End

Elevation.

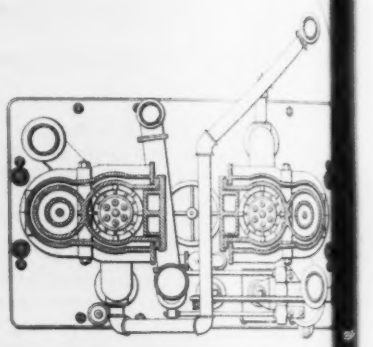


Side

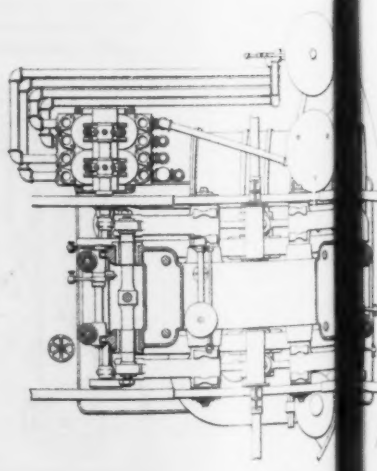
Elevation.



Top Plan.



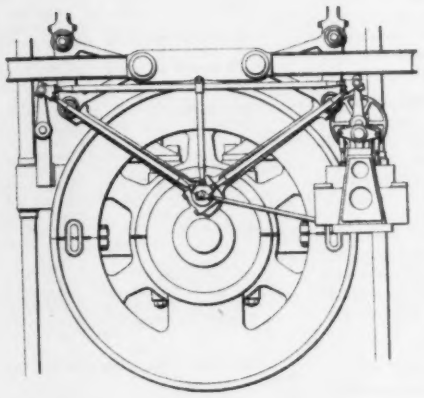
Sectional Plan
D-D.



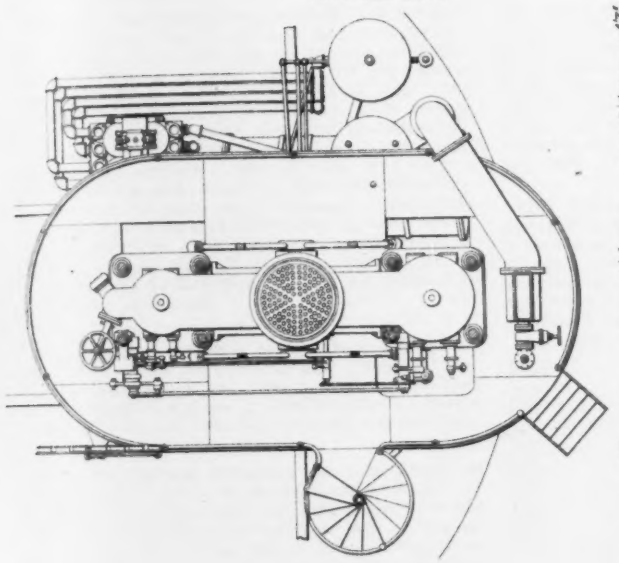
Sectional Plan

THE 700 H-P. NORDBERG VERTICAL PUMPING ENGIN F THE

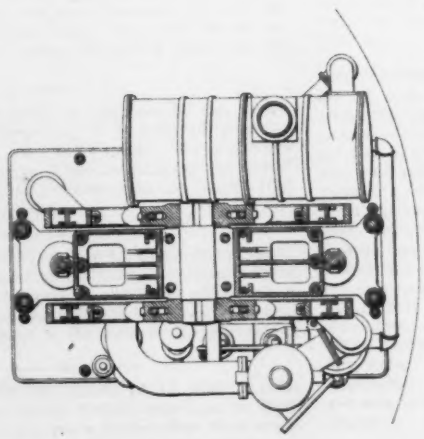
Nordberg Mfg. Co., M kee, Wis



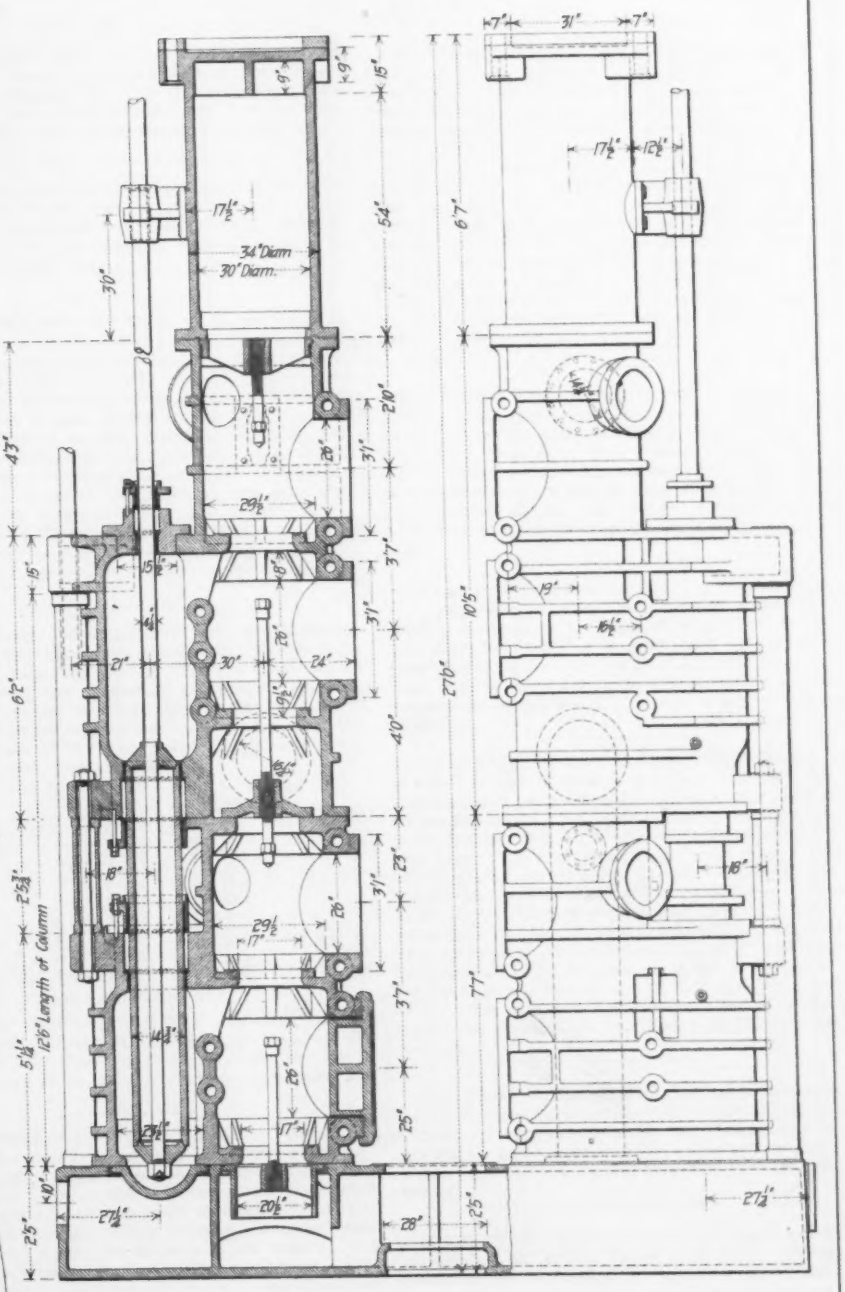
Feed-Pump
and
Valve-Gear Drive.



Sectional Plan
A-A.



Sectional Plan C-C.



Sectional Side Elevation
of
14¾ in. x 42 in. Pump.

F THE PENNSYLVANIA WATER CO., PITTSBURG, PA.

kee, Wis., Builders.

CHAS. HART, LITH., 24 VESEY ST., N. Y.